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THE JOURNAL OF THE AUSTRALIAN INSTITUTE OF AGRICULTURAL SCIENCE

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Manuscripts should be double spaced and should be submitted in duplicate, as part of the delay in referring is then avoided.

For more detailed information concerning the preparation and lay-out of scientific papers, authors are referred to the C.S.I.R.O. publication "Guide to Authors" and to an article entitled "The Preparation and Editing of Technical Papers" by N. S. Noble, published in the Australian Library Journal, April, 1954. The policy laid down in these publications is also largely followed by this Journal.

In addition to the contributions described above, the Journal is pleased to publish "Letters", "News Items", "Talks" and "Personal Notes" which have been received from, or which are of interest to, members of the Institute.

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ARTICLES

RADIATION FROSTS, THEIR CAUSES AND LOCAL PREVENTION IN AGRICULTURE

By D. E. ANGUS

Frosts can be classified into two types —radiation and advection.

The term "radiation frost" applies to clear calm conditions at night, in which heat is freely radiated from all exposed objects. This allows their temperature, and that of the layer of air adjacent to them, to fall below the danger point for horticultural crops.

The term "advection frost" applies to the incursion of a mass of cold air from polar regions. In such cases quite high wind speeds may be associated with the air movement, and the whole depth of the air may be well below freezing point. Fortunately such frosts are not encountered in the horticultural regions of the Australian mainland, and will not be dealt with here.

The extent to which the temperature falls during the night is a factor determining whether a frost will occur, and this temperature range depends on the nocturnal heat balance at the earth's surface. Over the last half century a number of preventive methods have been tried, the principle of each being to modify one or other of the components involved in this heat balance. The subject can therefore best be dealt with in terms of the various physical factors which affect the local balance of heat.

The severity of frosts depends, in addition, on the temperature at the start of the night and (in hilly country) on the presence or absence of air drainage. These two factors will also be considered.

Nocturnal Heat Balance

At night, all objects lose heat from their surfaces by radiation emitted to surrounding objects and to the sky, while the surfaces in turn receive radiation from other objects and from the atmosphere. If these were the only factors, the surface temperature would fall very rapidly. In doing so, however, it sets up temperature gradients whereby more heat is brought to the surface, by conduction upwards through the soil, by eddy conduction downwards through the air, and perhaps by release of latent heat from condensation and freezing of dew. These factors will be examined in turn in a qualitative manner. For those who desire quantitative data, a good treatment is presented by Brooks (1951).

Outgoing Radiation

The earth's radiation differs from that of the sun in its distribution of energy among the various wave-lengths of the spectrum. The maximum intensity of solar radiation lies at a wave-length of 0.5 micron (1 micron $= 10^{-4}$ cm), between the green and the blue in the visible portion of the spectrum. The maximum intensity of terrestrial radiation, however, is at a wave-length of about 10 microns, which is well into the infra-red region of the spectrum. For this reason, solar radiation is referred to as "short-wave" and terrestrial radiation as "long-

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wave". The earth and its vegetation is virtually a black body for long-wave radiation, i.e. it completely absorbs all such radiation falling on it.

Back Radiation

Although atmospheric water vapour and (to a minor extent) carbon dioxide absorb the greater part of the radiation emitted by the earth, they are not black bodies for this radiation. (See, for example, Anon., 1942, and Brooks, 1952). Consequently some of the emitted radiation can pass right through a cloudless atmosphere. The intensity of back radiation received by the earth's surface from these gases is therefore less than that originally emitted, unless the atmospheric absorbing layers are very much warmer than the surface, as could happen with an inversion, though very rarely.

If clouds are present, the water drops in them cause considerable radiative scattering and absorption, and the nett outgoing radiation is reduced. The lower the clouds, the stronger is the back radiation from them, as their temperature is higher than that of clouds at a greater altitude.

A clear night is thus much more liable to be frosty than one with low thick clouds.

Heat Flow Through Soil

The heat flow through the ground proceeds almost exclusively by molecular conduction, and is strongly affected by the condition of the soil. Although the thermal conductivity of all soil particles is much the same, that of a mass of soil varies considerably with the degree of packing of the grains, or the porosity. Thus quartz rock has a very high conductivity, but this is considerably reduced when it is powdered. The reason for this is the increased amount of air (a poor conductor) between the solid particles, as well as poor contact between them. If the air spaces in the soil are replaced by water, either from rain or irrigation, the conductivity is increased.

At night the soil surface loses heat by radiation, and heat stored in the ground during the day moves back to the surface. Although the thermal conductivity determines the quantity of heat passing, the rate of change of temperature at any point in the soil, due to the gain or loss of a given quantity of heat, depends on the "thermal diffusivity", defined as the thermal conductivity divided by the product of the density and the specific heat (Geiger, 1950, ch. III). In a dry soil, the diurnal temperature wave does not penetrate very far, but has a large amplitude at the surface. In a wet soil, it penetrates deeply, and the resultant surface amplitude is small. Since organic matter has an extremely low diffusivity, it acts as an insulating cover over soil on which it is placed, and its surface temperature fluctuates between wide extremes.

A more severe frost can therefore be expected with a dry soil than a wet one, and again where an organic mulch is spread over the surface.

Eddy Conductivity in the Air

From the soil surface in day-time, with its high temperatures, heat flows into the air as well as into the ground. Existing temperature gradients in the atmosphere would transfer heat at a negligible rate if molecular conduction were the only operative process. Another mechanism, known as eddy conduction, is acting, in which "packets" of air take the place of molecules.

The numerical value of the eddy conductivity of the air can vary considerably, the change being more than one thousand-fold. It has two components—a dynamic component caused by the turbulent streaming of the air, and varying with wind speed, and a thermal component originating from the buoyant instability of the day-time thermal stratification, so that it also depends on the temperature gradient in the air near the ground. It is thus affected markedly by the underlying surface, the values over a citrus orchard (Kepner, Boelter and Brooks, 1942) being quite different from those over bare ground.

Some of the heat carried into the air during the day can be brought back to the surface at night by sufficient air movement. The air adjacent to the ground at night is, however, colder and denser than the air above, and is therefore stable. This stability causes the wind at the lower levels to die away. The lower the wind speed, the less readily are the cold and warm air mixed, and the condition can easily arise where the layers of air near the ground are very cold, while the air becomes progressively warmer with height. Such a condition is called a "temperature inversion", and may extend up for some hundreds of feet, after which the air becomes colder with height in the usual manner. A typical nocturnal temperature pattern may be seen in Figure 1.

The amount of air movement also determines the temperature of vegetation relative to that of the surrounding air. In a strong wind the forced convection of heat to vegetation maintains its temperature at approximately that of the air passing over it. In calm conditions, on the other hand, vegetation which is losing heat by radiation can cool several degrees Fahrenheit below the temperature of the surrounding air before sufficient heat passes along the temperature gradient

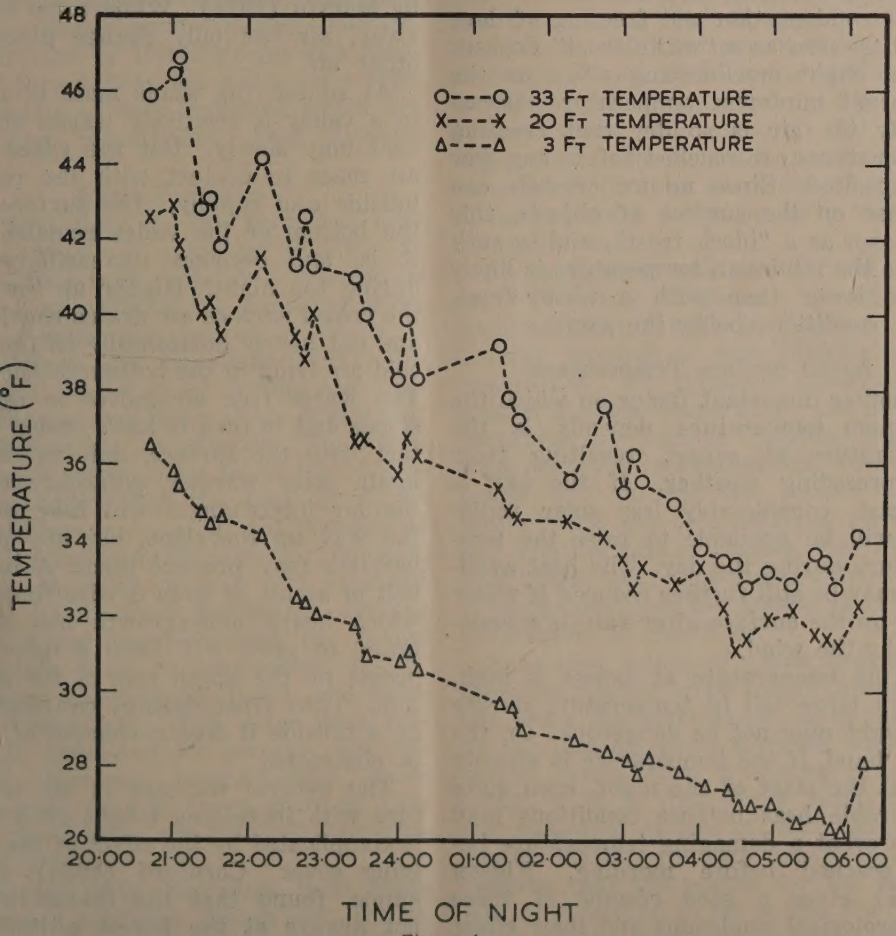

Figure 1.
The nocturnal pattern of air temperatures over grape-vines during a typical Spring radiation frost.

thus set up to compensate for the radiative loss.

For several reasons therefore a calm night favours frost damage.

Latent Heat

As vegetation cools during the night, its temperature may sooner or later fall below the dew-point of the adjacent air. This results in a vapour pressure gradient being set up, which causes water vapour to flow to the surface and condense upon it as dew. When dew is deposited, it liberates latent heat, which reduces the rate of fall of temperature. When it freezes, a further smaller quantity of latent heat is released.

The condensation and freezing of dew, which is seen as a "white frost" deposit, has a slight ameliorating effect on the nocturnal minimum temperature. Occasionally the air is so dry that freezing temperatures are reached before any dew is deposited. Since no ice crystals can be seen on the surface of objects, this is known as a "black frost", and in such a case the minimum temperature is likely to be lower than with a white frost, other conditions being the same.

Initial Surface Temperature

Another important factor on which the minimum temperature depends is the temperature at sunset, resulting from the preceding weather. If the sky is overcast, considerably less solar radiation will be available to raise the temperature during the day. The heat available may be still further reduced if water lying on the surface after rain is evaporated by the wind.

If the temperature at sunset is high, a very large fall in temperature during the night may not be dangerous. On the other hand, if the temperature is already low at the start of the night, even quite favourable heat balance conditions may not prevent a damaging temperature being reached before morning. Kidson (1927) gives a good résumé of these meteorological conditions and their effect on the likelihood of frost.

Air Drainage

All the previous remarks for flat land conditions apply also to hilly country, but in this latter case one other factor—air drainage—assumes importance. Cold air, being denser than warm air, always sinks to the lowest level consistent with its density.

Bush (1947, ch. IX) gives a simplified classification of land into three frost categories—donor (hilltops and high ground), intermediate (hillsides) and recipient (frost pockets). Actually the popular conception of cold air draining down slopes like water is not technically correct, as pointed out a long time ago by Marvin (1914). While water can flow away, air can only change places with other air.

At sunset, the whole mass of free air in a valley is relatively warm, and loses heat only slowly. But the edges of the air mass in contact with the radiating hillside cool rapidly. The surface air at the bottom of the valley remains where it is, and becomes increasingly colder during the night. Higher up the slopes, the cooled surface air drains slowly down and out nearly horizontally on top of the cold air lying in the bottom of the valley. The warm free air moves in upon the slopes and in turn is itself cooled by contact with the surface, only to exchange again with warmer adjacent free air. Similar interchanges will take place all the way up the slope, but any physical barriers may prevent them. A hedge, a belt of scrub, or even a wire fence along which heavy undergrowth has been allowed to grow will form a minor frost pocket on the uphill side of the obstruction. Thus frost damage can occur well up a hillside if free movement of the air is obstructed.

The general increase in air temperature with increasing height up a hillside is complicated by the effect of the underlying cover. Cornford (1938), for example, found that the coldest air was not always at the lowest altitude in a valley. By studying the temperature

effect of vegetation on level ground, and also on slopes, he found that it could be large enough to offset the effect of topography.

Preventive Methods

It is proposed in this review to consider only physical methods by which it may be possible to prevent damaging temperatures being reached over agricultural areas of a few acres. Other methods, of a more biological character, seek to protect crops while allowing them to remain in the presence of normally damaging temperatures. They include the development of plant varieties which are more frost resistant, and the use of hormone sprays to delay bud-burst until the danger period is over. The Imperial Bureau of Horticultural and Plantation Crops (1945) has produced a brief bibliography of such methods, which are still being investigated (e.g. Rogers, 1953).

Back Radiation

The first term in the nocturnal heat balance which it may be possible to modify is the back radiation. This can be increased by utilising the screening effect either of solid materials or of clouds or fogs. Rogers and Beakbane (1951) investigated the effect of netting and hessian screens, and there is no doubt that solid screens can be effective. The material of the screen must be of low diffusivity in order that the cooling of the outer surface may be carried through as little as possible to the interior (Geiger, *loc. cit.*, ch XLI), and in fact Primault (1951) found that parchment screens caused lower temperatures on plants underneath than on unscreened plants. Vegetables (Baughman, 1941), and small trees (Gustafson, 1952), have been successfully protected by screens, but the method becomes impracticable when large areas or tall crops such as full-grown fruit trees are involved (Durrenberger, 1956).

Attempts have therefore been made to create artificial clouds of smoke, chemicals or oil. German workers (Kessler 1935, and Kessler and Kaempfort, 1940) consider their use beneficial, although practical difficulties of sloping ground, displacement by wind, or chemical damage to vegetation may limit their use. On the other hand American workers (Kimball and Young, 1920, Anonymous, 1924, and Edgecombe et al. 1951) found that such methods were not effective.

The nature of the substance used is apparently of considerable importance. Randall (1948) states that experiments showed that a water cloud 50 ft. thick and with its base 50 ft. from the ground completely blocked the outgoing radiation, while a 300 ft. thick smoke only reduced such radiation by 35%. Collins (1946) found that a fog of oil droplets 0.5 micron in diameter was transparent to long-wave radiation, even with concentrations up to 2000 gall/hr/sq. mile, which was twenty times that required for visual obscuration. In contrast, natural moisture clouds (droplet size about 10 microns diameter) were found to have very low transmissivity.

An experiment was also carried out at the Chemical Defence Experimental Establishment (1947) in England, using a large number of zinc chloride smoke generators. At frequent intervals the ground surface temperature and air temperatures at various heights, together with radiation measurements, were taken inside and outside the smoke. These showed that the nett outgoing radiation, and also the rate of cooling, was reduced only about 15%, even though the density of smoke used was far greater than would be possible in practice.

Since the action of these hygroscopic chemical smokes is to adsorb water vapour from the atmosphere on to the particles, forming liquid droplets, and since water clouds have a strong absorbing effect, it is at first sight puzzling why the measured effects of such clouds are small. Geslin (private communication) believes that the reason for the failures with this method so far is that the dimensions of the particles obtained are too

small (generally not greater than 1 micron diameter). Since the maximum intensity of the wave-lengths we are interested in is at 10 microns wave-length, droplets should have at least this diameter for maximum absorption, (see e.g. Hilsum 1948), but they should not be too large, or they will fall out of the air too rapidly. Work is proceeding under his direction to determine whether fogs of suitably sized droplets can be produced on an agricultural scale.

Geslin's view is strengthened by measurements made by Arnulf, Bricard and Veret (1954). They found that in a light mist (several hundred droplets per cm^3, with most of them less than 1 micron diameter) the attenuation was small for visible radiation of 0.4 miron wave-length, and was practically zero for radiation of 10 microns wave-length. In thick fogs (numerous droplets exceeding 20 microns diameter) the attenuation was large for all wave-lengths up to 10 microns, and fell to zero only when the wave-length approached 100 microns.

Turning now from methods of reducing the nett outgoing radiation, it has been suggested that it might be possible to compensate for this loss by the use of infra-red heaters. Poppendiek (1953) has presented an analytical study of the thermal structure within individual citrus fruits that are artificially heated by radiant heaters.

An Anonymous (1939) article has described the installation of a citrus grower in America who used therapeutic infra-red lamps in his orchard. Gordon and Brooks (1940), however, used similar lamps in a cold room with orange and lemon trees without obtaining any protection. The Michigan State College also spent some years developing infra-red heaters (see Farrall, Sheldon and Hansen, 1946; Hassler, Hansen and Farrall, 1947 and 1948; Hansen, Gardner and Farrall, 1949; Hansen and Farrall, 1949). They found as might be expected, that the vegetation could be heated appreciably, although the air temperature was very little higher.

Their final design of oil-heated radiator was found to have certain limitations. High stack temperatures (1100° F and more) were required, resulting in fairly high fuel consumption. Less than 25% of the energy available was effectively radiated, and the area protected was not great, as the intensity of radiation decreases rapidly with distance from the heater. Also "shadows" were cast by the nearer vegetation, thus allowing shielded foliage to freeze. Tests in England by the National Institute of Agricultural Engineering (1950) give further experimental details of their effectiveness. Randall (*loc. cit.*) gives a good summary of the American work, but Macfarlane (1951) reports that it was abandoned, mainly because it was too expensive.

Heat Flow Through Soil

The flow of heat both into the soil by day and back to the surface by night can be increased by increasing its moisture content and by compacting it. King (1945) found, after a disastrous spring frost in South Australia, that those farms which had been dry the longest since their last irrigation suffered the worst damage, and that breaking up the soil surface by cultivating it after an irrigation tended to offset the value of the water.

These growers now extensively use the method of "heat conservation" by turning in their cover crops early in spring and then irrigating, special "frost irrigations" for this purpose being made available. This reduces the frost risk, as is evident from a comparison after a light frost with the few farms where cover crops are left standing. King (1948), however, reports that the protection diminishes gradually over a period of about three weeks from an irrigation.

Such a method involves certain dangers. If water is available for application as often as damaging conditions are

likely, the general water requirements of the crop must be carefully observed, to avoid damage by overwatering. There is also the difficulty of evaporational cooling of the soil surface during the day, which reduces its initial temperature at the start of the night. For example, Brooks and Rhoades (1954) took two test plots of 5 acres each in a pear orchard. The plots were disc-cultivated, and one of them was immediately lightly flood irrigated. A doubling of the heat flow rate through the soil was observed, but against that there was an evaporational cooling of the surface of 7° F. The watered plot took more than ten days to recover, but in fourteen days it had warmed up to a higher temperature than the unwatered plot, and then provided some frost protection.

If warm water is available on a large scale, e.g. from a bore, some protection is possible immediately after using it for irrigation. Jones (1924) irrigated a citrus grove early in the night with water at 72° F. The warming influence was about 1½° F, as found by comparing readings of thermographs in standard shelters in the test grove and in a nearby control grove.

Since the creation of furrows or clods on the surface considerably increases the heat insulating air spaces (see, e.g. West, 1932), compacting the soil surface after cultivation can markedly increase the flow of heat from below. Temperatures tabulated by King (1948, Addendum) show that strips of soil compacted with a roller immediately after cultivation had nocturnal surface minima from 2° F to 4° F higher than adjacent sections which had not been rolled. Similarly Kemp (1949) and Olsson (1953) found that the temperature above a bare packed surface was 1° F to 3° F higher on frosty nights than above mulched plots and freshly cultivated plots. A theoretical treatment of the effect of cultivation on soil temperatures has been given by van Duin (1954).

There is a fairly commonly held belief that increasing the "roughness" of a soil surface will increase the radiation loss by increasing the total exposed area. Actually this is not the case. With furrows, for example, part of the radiation loss by one face will be intercepted by the other face. The intensity of radiation emitted from a surface is independent of its roughness.

Vegetation growing on the soil has a similar insulating effect to cultivation. The top of the vegetation becomes the new radiating surface, but the flow of heat from below is hindered by air spaces in the vegetation. But removing a cover crop which is regarded as a frost risk will have little effect if the soil surface is thereby left loose. This accounts for the findings of Young (1922 and 1925), who concluded that cover crops have no adverse temperature effects. Temperature records were obtained on frosty nights in orchards divided into two sections, each with a cover crop growing in it. One section was then clean cultivated, and similar records were taken. The cultivated section was only slightly warmer (less than 1½° F) than that with the cover crop still growing. The reason for this small difference probably lies in the fact that the cultivated section was not compacted, so that the soil heat flow in this section would also be hindered. Rogers (1949) reports similar small differences in temperature between cover crops and cultivated soil, but once again if the bare soil surface was left loose, and not compacted, no valid comparison is possible.

Artificial electrical heating of the soil is a possible method, though it is doubtful whether it would be worth trying in the open. While it is often used in glasshouses, it has the objection that the presence of cables just below the soil surface interferes with cultivation, while the costs are also likely to be high.

Release of Latent Heat

Although the amount of dew deposited naturally at night is too small to supply

sufficient heat to prevent frost damage, except in marginal cases, fine water sprays, have been used successfully with certain crops. The vegetation becomes coated with a film of ice, the temperature of which does not fall below 32° F *as long as a change of state from water to ice is taking place.* Such a temperature is safe for most temperate agricultural plants, since frost damage does not occur until the sap freezes at a temperature several degrees below 32° F. If the freezing process ceases, however, a rapid fall in temperature occurs. For this reason the spraying must be continued in the morning until the air temperature has risen above freezing point and melted the ice casing on the plants.

The requirements for such a method are suitable irrigation equipment, a large water supply, a plant that can withstand the ice load without breaking (Rogers, 1952a), and of course good drainage. A graphic example of the possible effect of the weight of ice is shown in a photograph reproduced by Young (1940), where the weight of ice on the limbs of an orange tree tore it apart.

Both Mercanton (1939) and Kessler and Kaempfert (*loc. cit.*) give details of early experiments using this method. More recently work has been undertaken in a number of countries. In England Rogers and Modlibowska (1950), Rogers (1952b), and Rogers et al. (1954) give experimental results, the latest of which suggest that various rates of precipitation of the order of a few mm. per hour can provide protection against frost intensities up to 8° F. The capital cost of the equipment is high, but this can be offset by using it for summer spray irrigation. It is interesting to note that these workers, like the Americans mentioned in the previous section, have found that soil temperatures are reduced for about a week due to the application of this water.

In Germany, Witte (1951 and 1952) found that damage from 11° F to 12° F of frost could be prevented with a precipitation rate of 10 mm. per hour which, however, is too high a rate to prevent over-watering of the ground. Theoretically less than 1.5 mm. per hour should be adequate. It was also found that protection against up to 4° F of frost could be provided by watering the ground, which automatically occurs with the sprinkling method. Kidder and Davis (1953) in America used intermittent sprinkling with a rotary sprinkler but found that the period of rotation needs to be small. Jeffree (1950) also gives practical details of the use of a rotary sprinkler. Businger (1955) in Holland investigated the influence of a number of variables on the minimum precipitation rate required, and found it possible to draw up a precipitation formula embracing these variables. Dearborn (1948) successfully used sprinkling in the slightly different problem of keeping glass shelters above dangerous temperatures for sensitive plants grown inside them.

Field surveys of this method in practice by Roberts (1950) and Bilanski, Davis and Kidder (1954) show that it is already being successfully used to protect commercial flower and vegetable crops.

Before leaving this section, mention should be made of the claim that "washing off" the frost with water early in the morning after a frosty night prevents damage. Modlibowska (1953) conducted controlled experiments with fine thermocouples threaded through fruit buds, and found the very special conditions which must apply if this method is to be successful.

Direct Heating of the Air

Even since Roman times "smudging" fires have been lit in an attempt to prevent frost damage, but the first heating, as distinct from smudging, was apparently used in America about the beginning of this century. The use of heaters has become very wide-spread, and is the most consistently reliable method so far developed.

The successful use of heaters depends on the presence of a layer of warm air overhead, beneath which a vertical circulation can be set up, so that in effect they produce a transfer of heat through the air to the lower levels. Young (1940) gives probably the clearest account of the actual mechanism of this method. The greater part of the heat given off is in the form of a rising column of hot gases and heated air. The temperature of this column is gradually decreased as is mixes with the surrounding cold air. If there were no warm air overhead, the column would rise to a considerable height. With a temperature inversion, however, the hot column does not rise very far before it is surrounded by air at the same temperature as itself, so that its upward movement is stopped. The air carried up from the heaters at ground level has to be replaced, so that a circulation of air is set up beneath the inversion. Apart from the small percentage of radiant heat available, it is this warm air brought down from overhead which heats the lower crop levels.

Any natural drift of air will carry off the heated air as it rises, thus diminishing the effect of the heaters. This heat is not completely wasted, however, as Angus (1955) has found that under these conditions the influence of the heaters may extend for considerable distances downwind of the area in which they are placed. Again, near the edge of an area of heaters, the air carried up from the heater level is replaced by cold air from outside the area, instead of a circulation being set up beneath the inversion layer (see Kepner, 1952). The updraft from an isolated heater area thus draws cold air in from *all* sides of the area, and this "border effect" reduces the effectiveness of the outer heaters.

A large number of small heaters, providing air at a temperature not much higher than their surroundings, will be more effective than a few large heaters with the same total heat output. These latter produce columns of air of such high initial temperature that they rise a considerable distance before being brought to rest. Again, if the natural air temperature increases very rapidly with height (a "strong" inversion), the heated air will not have to rise as far as when the air temperature increases only slowly with height (a "weak" inversion). Priestley and Ball (1955) have shown theoretically that the height to which a convective column ascends depends on the vertical temperature profile of the surrounding air, the source strength, and the rate of spread of the column. Strangely enough, the temperature distribution in such convective columns has been very little investigated, although Cleeves and Boelter (1947) give some experimental data.

Considerable investigation of heaters has taken place over the years, but the main experimental results are presented for individual heaters by Hoffman (1927) and for field trials by Kepner (1951). The piping of warm air to each tree in an orchard has also been attempted in America (Thompson, 1937b). Schoonover, Brooks and Walker (1939) claim, however, that installation costs are too high, and that it proves impracticable unless the air is perfectly calm.

While heaters were, until recently, acknowledged to be the best form of protection, there have been certain changes in recent years. One of the greatest changes has been due to regulations against air pollution (Macfarlane, *loc. cit.*). The smoke nuisance of heaters had always been recognised, and the smoke production of various types of heaters investigated (Schoonover and Brooks, 1932). This resulted in the development of heaters of high efficiency, such as the "return-stack" type (Leonard and Kepner, 1950).

The simpler and cheaper forms of heaters have now been banned in certain fruit-growing States of America, owing to their high smoke output, which contributed towards a very considerable smog

nuisance. The approved types of heaters are more expensive, and there have also been rising costs in fuel and labour. High operating costs have produced a tendency not to light up until absolutely necessary, and the cost of a season's heating can be wasted by one subsequent failure to light up. All this has created an opportunity for the introduction of wind machines. The promise of lower operating costs to offset their higher initial cost, as well as their automatic operation at the first warning of dangerous temperatures, is a considerable inducement.

Mechanical Mixing of the Air

While heaters use thermal energy to cause a convective circulation of the air, they use it very inefficiently. Wind machines, on the other hand, achieve the same purpose by using an air jet to mix the warm air overhead with the cold air at crop level. In effect, the eddy conductivity of the air is increased many-fold to bring back to the earth's surface heat which was carried upwards during the day.

Wind machines, an example of which is shown in Figure 2, came into use in America after the First World War (Moses, 1938), and although the results of the early trials did not appear promising, their practical success has led in recent years to a tremendous growth in the number installed. Published figures on their successful performance were apparently not available, until the summaries of Thompson (1937a), Moses (*loc. cit.*) and Brooks (1947).

In the last few years considerable field work has been conducted in America to determine their effectiveness, and the results have been published in a series of papers: Brooks, Kepner and Yerg (1948); Brooks, Rhoades and Schultz (1950); Brooks, Kelly, Rhoades and Schultz (1951); Brooks, Rhoades and Leonard (1952, 1953 and 1954); Rhoades, Brooks, Leonard and Schultz (1955). Similar results have been obtained in Australia (Frith, 1955) and van Eimern

Figure 2.
High-powered American type wind machine installed in a citrus orchard near Griffith, N.S.W.
(Photo. by courtesy Australian Journal of Agricultural Research.)

(1955) is now experimenting with them in Germany.

In other parts of the world it has been felt that a more efficient machine would use a propellor to draw down warm air from the inversion layers directly and spread it around the crop. In both England and Australia large diameter airscrews rotating in a horizontal plane, and exerting a direct suction effect on the air above, have been tested. Helicopters have been tried occasionally, but it has proved dangerous to manoeuvre a helicopter at night close to the tree-top level.

"Frost fans" (as these large vertical-axis airscrews are called) have been tested in England (Courshee, 1949 and 1950), but it was finally decided that there was no prospect of an economic solution to the frost problem by this means. After a few years of tests in Australia, Frith (1951) also concluded that the range of such machines was insufficient to consider them as an economically practicable form of protection.

Subsequent Australian work has shown that while the warm air is brought down very successfully by such fans, it is not mixed efficiently with the cold air around the crop, and is quickly lost again by buoyancy, thus limiting its horizontal range. Considerable work has now been done in Australia on the fundamental mechanism by which wind machines achieve their effect, and considerable improvement in performance over the older type of frost fans obtained. This work will be reported in detail in the near future, but one model is shown in Figure 3.

Since the action of wind machines is to mix the inversion layers, their effect will be less on nights of weak inversion. In cases of advection frosts, i.e. no inversion at all, they will have no effect. The effect of heaters also depends strongly on the inversion strength, but when this is weak suitably placed heaters can afford a little protection, both by the rising warm air enveloping the plant parts, and also by direct radiative heating of the crop. When a wind machine in combination with heaters is used to drive the warm air against adjacent foliage, better protection might be expected in the case of advection frosts, or radiation frosts with weak inversion. This is what Brooks, Rhoades and Schultz (*loc. cit.*) have found in citrus, although Angus (*loc. cit.*) found that this was not the case for a very low-growing crop.

Figure 3.

Low-powered C.S.I.R.O. experimental wind machine. In the foreground several return-stack orchard heaters can be seen, and in the background a mast on which temperature elements are mounted to measure the strength of the inversion.

Nevertheless, a combination of wind machines and heaters is the standard protective method now used in America, the wind machine on its own being used on strong inversion nights (low ceiling), and being supplemented by a small number of heaters on weak inversion nights (high ceiling). Adams (1952) and Rock (1953) give cost comparisons of heaters and wind machines, used separately and in conjunction.

An Assessment of the Methods

The foregoing methods fall into three distinct groups:

1. Methods which seek to prevent the formation of a stable air mass.
2. Methods which, in the presence of a stable air mass, add energy directly to the plant.
3. Methods which seek to modify the stable air mass by adding energy to it.

The first group consists of methods of reducing the nett outgoing radiation and increasing the heat flow from the soil. Increasing the soil heat flow can never have more than a minor effect on the formation of a stable air mass. Nevertheless, for light spring frosts, where conditions occasionally just border on the damaging, wise cultivation practices can probably swing the scales in the farmer's favour.

On the other hand, the use of an artificial fog to reduce the outgoing radiation offers, of all methods, the greatest promise, if the difficulties in its use on

a large scale can be overcome. An investigation into the possibility of producing clouds of adequate thickness with suitably sized water droplets, on an agricultural scale, seems to present the most potentially fruitful approach to the problem at the present time.

In the second group of methods, energy can be supplied by radiant heat, or the release of latent heat in water sprinkling. These methods should not be lightly dismissed, as they are the only ones inherently capable of succeeding with advection frosts. In view of the disadvantages associated with radiant heaters, it seems unlikely that this method can ever enjoy widespread success. The use of sprinkling to release latent heat likewise has certain disadvantages, but in cases where a farmer has an overhead sprinkler irrigation system, and has water available at the right time, this method might well be considered.

The methods in the third group are the ones which have so far been most widely used, but up to the present they have required far larger quantities of energy than are theoreticaly necessary. It appears that the introduction of small quantities of energy at a large number of points, rather than large quantities of energy at a few points, makes for greater economy. Such increased efficiency has, however, to be viewed in the light of the increased cost of a large number of sources.

Although with heaters the properties of a stable air mass are used to create a convective circulation, and hence a redistribution of energy within the mass, a large quantity of heat is required to accomplish this. It therefore appears that the cost of fuel will always be a limiting factor in the widespread use of such a method, as indeed of recent years it has.

Wind machines, on the other hand, use a comparatively small amount of energy to produce the vertical redistribution of heat. For this reason their further development appears attractive. Ball (1956) has computed that less than 0.1 h.p. per acre is theoretically necessary to keep an inversion layer about 30 ft. thick completely mixed when heat is being removed at the bottom. Whether the expenditure of such small amounts of energy will ever be adequate for the areas it is desired to protect, only further investigation will show.

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THOUGHTS ON AGRICULTURAL EXTENSION

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We have reached an opportune stage in our agricultural development for a co-operative appraisal of the problems of agricultural extension. Our basic extension policies should be defined in a written agreement setting out the part to be played by all Federal and State agricultural agencies. We are strong in technical knowledge, much of which is not being put into practice on our farms because of lack of knowledge on the skills of extension. We know what to teach but very little on how to teach.

These, in brief, are my thoughts after spending three years in the U.S.A. and watching at close range the Cooperative Extension Service with its varied array of successes and failures. In view of the agricultural and political similarities between Australia and the U.S.A., I feel we would do well to draw from the wealth of American extension experience and make an objective appraisal of our present extension philosophy.

Where We Are

In some respects Australian extension work is approaching a fork in its road of progress. We can choose either our present policy of uncoordinated extension activity, or a cooperative approach. A similar choice was presented to American extension administrators some 50-odd years ago. They chose a cooperative approach, based on the Smith-Lever Act of 1914. History has shown that both Federal and State agricultural agencies have derived mutual benefit from this decision, particularly the latter, which have expanded considerably since 1914.

We are now at a similar stage to that of the U.S.A. at the turn of this century in terms of immigration; secondary industry development is having its impact on rural life and, for the first time, we are experiencing the influence of population pressure on agricultural exports. At the same time we are in a period of rapid agricultural expansion; we have a new vision of the agricultural potential of our country.

Crawford (1954) has summarised this thought in his quotation taken from *National Development*:

> "The picture has changed from one of frustration if not despair, to one of a real and gathering forward momentum in rural production."

Of the professional agriculturists involved in this expansion, key men are extension workers in the various State Departments of Agriculture. Increased production will depend on the technical knowledge of these men and their skill as educators.

To be sure, we have problems but they are of youth rather than senility; we are deficient in trained staff, and there are many technical problems associated with agricultural development that are still unsolved. However, I feel the most important lessons we can learn from agriculture in the U.S.A. are not those associated with agricultural research. It was part of my work in the U.S.A. to arrange American itineraries for Australian research workers; their reputation with their American counterparts speaks for

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itself on the high quality of our agricultural research.

Similarly in the extension field, our technical knowledge is sound; in general terms, Australian farmers, provided they ask, can get as sound technical advice in Australia as their counterparts can in the U.S.A., thanks to the technical knowledge and integrity of our State extension workers.

But what of our weaknesses? Underwood (1952) summarises them thus:

> "Agricultural research and extension in Australia have suffered too long from an almost exclusive devotion to technical problems and a severe neglect of economic and sociological problems."

To this statement, I add one further point: we have no mechanism whereby local extension workers can integrate extension programmes with national trends. This does not imply that extension men should be Federal employees. The American experience is overwhelmingly in favour of extension work being primarily a State responsibility. The responsibility of the Federal Extension Service is to integrate research information from all sources, encourage the extension workers to think in terms of national and interstate progress, and offer what help the States feel can be handled more efficiently by a central body.

Even as Federal research in Australia has helped State research, so too can State extension men benefit from Federal help in solving these problems suggested by Underwood.

Sociological Problems

The general philosophy that an extension worker is asked to adopt in the U.S.A. is that of a rural educator. He is not a "fix-it" man whose job it is to "tell farmers what to do". His product should be mature, enterprising, rural people. Success in these terms is difficult to measure; it is tempting to measure progress solely in tons per acre, dozens of eggs, etc. The experience in America has shown that production rises automatically when once a farmer realises his objectives, which, of course, are sociological; technical information is the essential aid used by the extension worker for reaching these objectives.

This means that in addition to technical knowledge an extension worker needs a background knowledge of extension psychology, skill in using the right extension methods at the right time, and he needs guidance on sociological aspects of rural life. His skills in these fields are equally as important as his technical knowledge.

The skills required for extension work among the potato growers of Tasmania are basically the same as those needed in the sugar producing districts of north Queensland. The product is a sociological one in both places. Basic answers to our extension problems can be applied in all States. However, they need local modification and each State has a responsibility to adapt them for its own use, even as each State is responsible for modifying the research results of C.S.I.R.O. as spread by the Agricultural Research Liaison Section. Unity without uniformity should be our aim.

Brief schools to train field men in the skills of extension are held in some States in Australia. We need to build on them; extension workers should be able to work towards a post-graduate degree in agricultural extension as a subject in its own right. Our deficiency in this regard is not surprising; apart from overseas gleanings we have little to offer at extension schools. We have no national research unit evaluating extension methods and there is no mechanism for pooling the wealth of extension experience we already have. Even as we have research journals, so too do we need an extension journal. Our lack of extension information is no reflection on the ability of State extension workers but it is a reflection on our lack of a central clearing house for extension experience.

We need evaluation studies on our effectiveness in extension. When an extension worker succeeds he should know why he has succeeded, similarly we should know reasons for his failures. Moule (1952) reports that some American Extension Services have spent up to 10 per cent. of their extension budget on evaluation studies, i.e., in finding out how they could spend the remaining 90 per cent. more effectively. Apart from a very few evaluation surveys (e.g., the recent survey of the N.S.W. Department of Agriculture, M.I.A. Agricultural Service) we have no guides on which to base future extension activities.

Economic Problems

National implications of our national economic trends are not closely integrated with local extension programmes. The over-all benefit from any production increase is a national one. An improvement in farming efficiency in potato production in Tasmania has its impact on the sugar producer in Queensland; that is, a close liaison between economic research and extension activity is for the national good.

The trend in American extension is for the economics specialist to play an increasing role in extension activities. A national Economic Outlook Conference is held annually and attended by State extension economistts. They, in turn, adapt their own State extension programmes in the light of these national economic trends. The County workers localise this advice in working with farmers. Farmers planning committees weigh up what they want with what is economically sound for their locality. We have in the Bureau of Agricultural Economics the agency for determining these trends; we have State economic specialists to take the findings a further step, but there is no linking mechanism, so that each State extension worker can modify his activity in the light of national economic trends.

An Example

At present "Farm and Home Planning" is a popular topic for discussion in American extension circles. This trend for individual farm planning began in Missouri during the economic stresses of the 1930's. The idea seemed good. A few other states took note and began similar programmes. Now the Federal Extension Service is sifting the lessons learnt and last year embarked on a major programme to explain the idea to other states so that it could be adapted to their own conditions. Extra staff were needed in the counties so the Federal office obtained an extra $7 million for allocation to the states. Within twelve months pilot schemes were started in practically all states, California being a notable exception. I venture to say that if there had been no coordination, no central body to sift the strong points from the weak and to arrange schools and conferences for extension workers, twenty years would have gone by with very little done.

This is not dictation; the States can accept or refuse what is offered. California, for example, has decided to "listen and watch" for the time being. The Federal office takes part merely to explain what the idea is and to look out for new ideas. If Californians wish to abstain their very abstinence is a point to be studied as the programme develops. California's share of the increase in Federal allocation is not denied them, even although they are spending it in appointing subject-matter specialists at the present time.

What We Might Do

The overall success of the extension work in the U.S.A. seems to depend on Federal, State and County extension officers recognising that each has a part to play. The basis for this seems to lie in the various Memoranda of Understanding signed by the U.S.D.A. and the States following the passing of the Smith-Lever Act.

I feel we would do well to consider a similar arrangement in Australia, taking into consideration the differences in Governmental structure between the two

countries. There is a need for the Department of Primary Industry, C.S.I.R.O., State Departments in Agriculture, Universities, A.B.C. and other public agencies interested in agriculture, to define their various responsibilities and co-ordinate them in a written agreement. This might be administered by the Standing Committee of Agriculture.

In the field of technical information we have the *Agricultural Research Liaison Section* of C.S.I.R.O. making available to extension workers the results of Federal agricultural research. In addition, we need an *Agricultural Extension Techniques Unit* to study the problems indicated by Underwood. These are national problems. A small Federal Section could serve a useful purpose without detracting from the current State extension activities. This Section might:—

1. Study the relative value of extension methods. Publicise, on an interstate basis, extension techniques already developed in Australia. Evaluate overseas experience for further trial by State extension workers.
2. Do extension evaluation studies at the request of States.
3. Hold conferences on the philosophy and methods of extension. These might be of an interstate nature with experienced State extension workers contributing.
4. Make available from the social science departments of Universities and the Department of Rural Broadcasts of the A.B.C. information

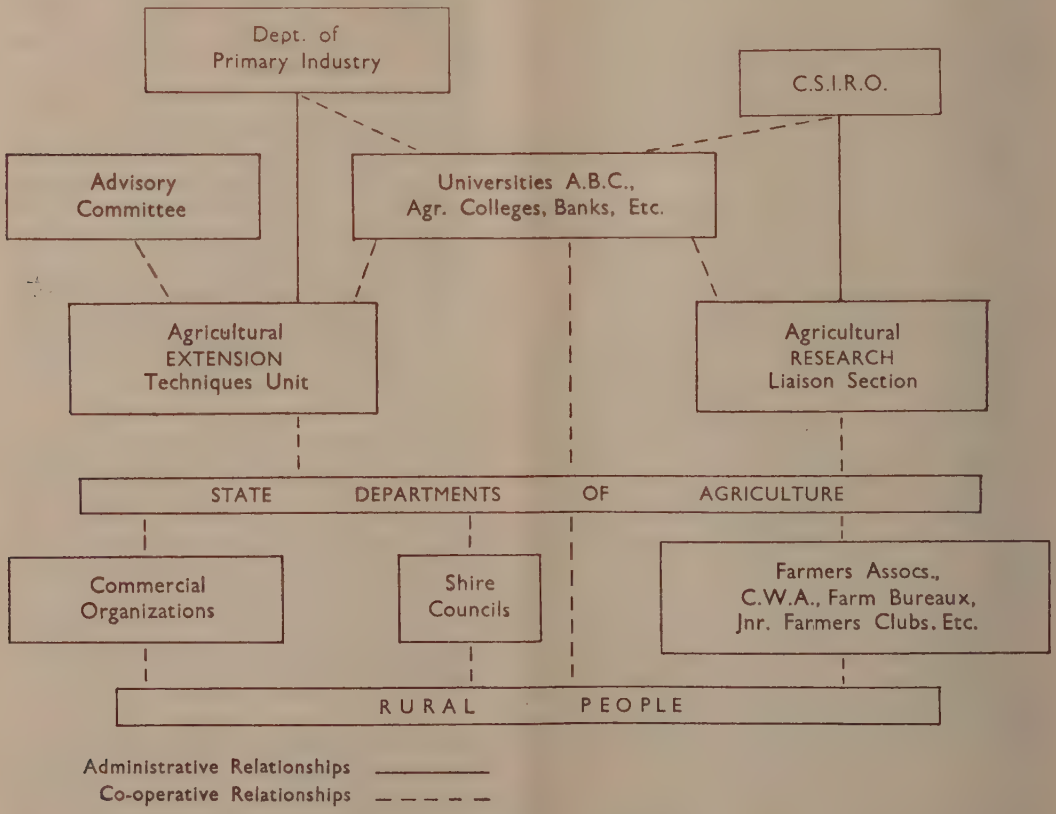

Figure 1.

likely to be of value to extension workers.

5. Arrange economic outlook conferences.

The activities of this unit might be based on a written agreement between the unit's parent department and each State Department of Agriculture. It may be necessary to have more than one agreement to allow for the different structures of each State department. This need be no handicap. The administrative structure of each Department of Agriculture is purely a State matter.

Of the Federal departments which might foster such a section, the Department of Primary Industry appears to be the most suitable. It is the main source of economic information of national importance and it is administering the Commonwealth Extension Grant, which might finance a section such as is suggested here. Alternatively each State might contribute some of its share of the Commonwealth Extension Grant to finance the section.

C.S.I.R.O. does not seem the appropriate body to foster such a unit; it is a source of technical information, the supply of which is already being handled by its Agricultural Liaison Section.

It seems that with the formation of a small *Agricultural Extension Techniques Unit* we have all the parts for a machine. To get this machine working and producing results we must join the parts together and figure 1 gives a diagrammatic representation of one way this might be done.

This diagram gives, of course, a simplified picture of a complex structure. One aspect not discussed so far is the Advisory Committee. This, I feel, should be an active body, made up of State extension administrators who would in practice constitute the senior extension committee in Australia.

Conclusion

These suggestions are offered to promote discussion. Of the governmental organisations active in the early days of extension development in America, the U.S.D.A. seems to have taken the lead; for example, Seaman A. Knapp, one of the fathers of agricultural extension, was a Bureau of Plant Industry employee. Extension work by the land-grant colleges was developing but in its infancy. In Australia, the State Departments have been, and will continue to be, the dominant forces in extension. Perhaps both countries will arrive at a similar extension philosophy, that is extension work on the farm is a State responsibility. Federal assistance is there to encourage the extension worker to do a more efficient job for the national good.

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SUBTERRANEAN CLOVER STRAIN BREEDING FOR THE WHEATBELT OF WESTERN AUSTRALIA

By A. J. MILLINGTON

The soils of the wheatbelt of Western Australia are notorious for their variability, but they can be broadly classified as lateritic gravels and sands, red brown earths and solonised brown soils. The pattern of increasing soil alkalinity with declining rainfall is complicated by the fossil podsolised soils of pH 5.0-6.3, which comprise between one half and two thirds of the wheatbelt and extend beyond the limits of cultivation.

In common with comparable regions elsewhere in Australia, the wheat growing areas were developed by applying superphosphate and by fallowing. The modest inherent fertility of the virgin lateritic sandplain soils is rapidly depleted, so that considerable attention has been given, over the years, to the establishment of suitable legumes on them.

The Western Australian Blue Lupin, possibly *L. Cosentini* (J. S. Gladstones, private communication) and the Dwalganup strain of sub-clover have been the most extensively planted legumes on the lateritic and on the red-brown earth soil types.

Because subterranean clover is a relatively closely self-fertilised species, reasonable genetic homozygosity is inevitable, and inbreeding after an artificial cross is unlikely to be associated with any marked diminution in yield. This basic genetic difference between sub-clover and the cross-fertilised pasture species, such as white clover and rye grass, which have received so much attention from the breeder, calls for a different approach, based more on the methods used with cereals. Like the cereals, subterranean clover is an annual, and this group is usually more self-fertile than the perennials. Seed increase is no problem where self-fertilisation prevails.

Subterranean Clover Breeding in Australia

Soon after the appreciation by Adams (1924) of the presence of strains within subterranean clover in Australia, there came the first attempts to create a new variety to combine the early maturity of Dwalganup with the greater leaf production of Mt. Barker. This investigation was made by Trumble (Donald and Smith 1937) who in 1929 obtained an "F_1 generation intermediate in all important characteristics. The F_2 comprised earlier types, which tended to the low yield and stemminess of Dwalganup and later types which combined the better yield and leafiness of Mt. Barker". The plants of these two generations were raised in spaced rows and after the examination in the F_2, they were abandoned.

The second use of crossbreeding was commenced in 1940 when McMillan raised four F_1 plants of a Mulwala by Mt. Barker cross, with a view to ascertaining whether improved rust resistant varieties could be produced. Mt. Barker is very susceptible, whilst Mulwala is early maturing and resistant to rust. Loftus Hills (1944) found that, apart from rust resistant progeny "the early types included a proportion of plants which were more attractive than Mulwala right through their life history, being leafier and more vigorous".

The present investigations were commenced at the W.A. University Institute

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of Agriculture in 1949, following a suggestion to the Merchants Agricultural Research Trust by the Director of the Institute, Professor E. J. Underwood, that the possibilities of breeding, as an aid in extending the subterranean clover belt in Western Australia, be investigated.

Breeding for Yield

When the breeding programme was commenced, it was generally believed that the principal aid in extending the subterranean clover belt would be the development of a strain which flowered before Dwalganup. This conclusion was based on the restriction of the later maturing strains to the areas of higher rainfall, where the effective growing season was longer. Analogy was made, also, to the role which early maturing cereals had played in the extension of the wheatbelt.

The polygenic nature of maturity suggested that transgressive segregation might result in earlier maturing selections, and the (Yarloop x Williams) cross did yield such F_3 lines, when grown at Muresk College in 1951. Although they flowered several days before Dwalganup, they were stemmy unproductive types.

One hundred F_4 lines, of Dwalganup, maturity, derived from crosses between Dwalganup, Williams, Yarloop, Pink Flower, Mulwala and Bacchus Marsh, were planted in a replicated small scale sward trial, on a lateritic sandplain soil type, at Merredin Research Station in 1952. Some of these crossbreds have persisted into the fourth season, following growing period (May-October) rainfalls of 647, 920, 859 points respectively. The performance of these crossbreds, suggests that strains can be developed which will persist on these soil types through most of the wheatbelt.

Meanwhile, consideration was given to the problem of producing strains which would not only persist, but which would be superior agrostologically. During the green feed period, leaf material constitutes the most nutritious part of the plant, while the seeds represent a protein-rich reserve for the summer months. It appeared desirable to endeavour to develop strains which produced mostly leaf and seed.

The variety Burnerang had been shown by Donald and Smith (*op. cit.*) to produce a significantly higher percentage of leaf than any other variety tested and for this reason to be a useful parent.

Varieties appear to differ widely in their seeding habits, and Dwalganup has the reputation of setting relatively few seeds above ground. Mt. Barker and Tallarook form many burrs aerially and since they flower later in the season, when conditions are usually less favourable for burr formation, it was assumed that capacity to form burrs above ground might be a desirable character in an early maturing variety. The variety Burnerang not only forms most of its seed above ground, but Aitken and Drake (1941) have shown that it is relatively efficient in terms of burr production per inflorescence. The characteristic of seeding aerially may be of particular value on heavy soils, the surfaces of which set in dry spring weather and prevent seed burial.

The "Erect" Burnerang Habit

As it has a very erect growth habit and an almost total absence of long lateral runners, the variety Burnerang has been termed a "genetic dwarf" by Donald and Smith (*op cit.*).

Burnerang is a late maturing variety and was first recognised at Burnley in 1929, as an "off-type" in a row of "Wangaratta", seed of which was collected on the property of the late Mr. D. Henderson at Oxley near Wangaratta (Aitken private communication).

The first generation of a cross made in 1949 at the Institute of Agriculture between Yarloop and Burnerang was a normal spreading type, while the F_2 population contained both erect and spreading types, Figure 1.

Figure 1.
Second generation of (Yarloop x Burnerang) showing the segregation of both erect and prostrate types.

Of the forty-two rows of F_3 segregates raised at Muresk College in 1951, ten were homozygous for the erect Burnerang growth habit. As Figure 2 shows the seed production was highly satisfactory on those erect plants which were sufficiently early to mature in this region where the growing period is relatively short. Much of the seed was formed above the ground, but none of the segregates was sufficiently early to be of direct value in the wheat-belt. To obtain erect, early maturing types, crosses were made between a (Yarloop x Burnerang) crossbred and the varieties Morocco and Dwalganup and a (Dwalganup x Red Leaf) crossbred.

In the F_2 of the cross (Yarloop x Burnerang 705.14.2 x Morocco) erect Burnerang types amounted to 32 in a population of 102. This segregation, also, is consistent with the "Burnerang" gene being a simple recessive ($\chi^2 = 2.21$ N.S.).

The subsequent breeding programme has aimed to incorporate this gene in plants at the "early" end of the maturity scale, with a view to breaking the association between "stemminess and earliness" noted by Trumble (*op cit.*). Figure 3 shows the two parental types and an

Figure 2.
Seed production on (Yarloop x Burnerang) F_3 showing the above ground seeding.

TABLE I.

Leaf-Stem-Burr-Seed Ratio, Lesmurdie 1954

Index	Variety	% Leaf	% Stem	% Burr	% Seed	Plot Yield gm.
A	Geraldton	10	33	53	4	134.1
B	Dwalganup	11	28	53	8	160.1
C	(Yarloop x Burnerang) 705.3.2	31	25	34	10	242.8
D	Bacchus Marsh	26	41	29	4	103.0
E	Tallarook	27	34	32	7	159.7
F	Yarloop	21	40	30	10	129.7
G	Burnerang	34	29	27	10	225.5

Significant Differences

($P < .05$)

Leaf .. CG > FAB
GCDEF > AB
Stem .. N.S.
Burr .. AB > CDEFG
Seed .. BGFC > A
CFG > D
Plot Yield .. CG > ADF

erect-type F_2 from the cross between (Yarloop x Burnerang) 705.14.2.10 and Dwalganup.

A sward trial, using 4 square link plots and three replications, was conducted at Lesmurdie (near Perth) during 1954 to obtain data on the relative proportions, at maturity, of stem, leaf, seed and burr in the normal spreading type, as compared with the erect Burnerang types. The gene was available in the parent Burnerang and in the (Yarloop x Burnerang) crossbred 705.3.2, which matures at much the same time as Bacchus Marsh. The trial was located in a high rainfall district (about 45") in order that the late strains would mature. The analysis of each variety into its components is given in Table I.

The very high percentage of the total production of the early varieties, which is in the form of woody burr material of low nutritive value, is corrected in the erect types. Moreover, the production of leaf is relatively better.

The Geraldton strain in relation to seed setting.

A contribution to the problem of obtaining superior seed setting may come from the Geraldton strain. This variety was collected by the author in August 1950, on the Mullewa road twelve miles east of Geraldton. It was observed in 1953 at Merredin that although this strain flowered 1-2 days later than Dwalganup, it matured 7-10 days earlier. This is due to the seed burrs of the Geraldton strain developing much more rapidly, than do those of Dwalganup, Figure 4.

This characteristic appeared likely to shorten the period during which seed setting was likely to be most adversely affected by the onset of summer. Trials to date in the outer wheatbelt suggest that the relatively rapid maturation of the burr results in better seed setting and hence survival.

While Geraldton has considerable merit in itself, it is chiefly as a source of superior germ plasm for seed setting under adverse conditions that it is likely to make its major contribution, and it has been used in crosses for this purpose.

Winter vigour

While rapid seed maturation appears to be a likely aid in extending the subterranean clover areas, it tends to shorten

the length of the green feed period. Investigations by D. K. Giles (private communication) at Irishtown, near Northam in the Avon Valley, have shown that within a few years of establishing Dwalganup sub-clover, two factors tend to limit the number of fat lambs which can be produced per acre. These are, firstly, poor pasture growth during the winter, particularly when the opening rains are delayed until late May and secondly, the few seasons in which Dwalganup can be cut for meadow hay.

Although the winter temperatures in the West Australian wheatbelt are not extremely low, it was noted in 1952 that the growth made by some of the strains introduced from Rabat in Morocco by C.S.I.R.O. was greatly superior during the cold weather, to that of Dwalganup. Although their winter production is very good, Figure 5, the earlier maturing Morocco strains are poor agrostologically, giving very stemmy adult plants with relatively little leaf or seed.

It appeared that the Burnerang gene for erect growth habit might enable the inheritance for vigorous winter growth to be used most effectively and in 1952 a cross was made between a (Yarloop x Burnerang) crossbred and Morocco N.1618. As none of the F_2 plants appeared to be equal in vigour to Morocco, two male sterile F_2 plants from this cross were crossed in 1954 with Morocco N.1619. It is hoped that by such crosses, strains will be obtained which combine the vigorous winter growth of Morocco with the leafiness of the erect Burnerang parent and the rapid rate of seed matura-

Figure 3.
Left to right: (Yarloop x Burnerang) crossbred, Dwalganup and F_2 crossbred.

Figure 4.
Burrs of Dwalganup (right) and Geraldton photographed sixteen days after anthesis.

tion characteristic of Geraldton. These can then be tested against Dwalganup in the wheatbelt.

Genetic Studies

Red leaf

The development of a red anthocyanin pigment, which masks all the normal leaf markings, is characteristic of the variety Red Leaf.

Red Leaf was crossed with the varieties Dwalganup, Yarloop and Bacchus Marsh and the F_2 crossbreds raised. The F_1 first leaf is green, with a red midrib, but the subsequent leaves are red. This dominance was studied in F_2 and found to give a simple 3:1 ratio in the crosses (Yarloop x Red Leaf), (Red Leaf x Dwalganup), (Dwalganup x Red Leaf) and (Red Leaf x Bacchus Marsh).

"Red Leaf" may be of value as a marker gene in genetic studies and as an aid in seed certification.

Linkage of flower colour and leaf crescent

The cross between Bacchus Marsh and Pink Flower gave an F_1 with rather smaller leaves than the ovule parent, but carrying a similar crescent. The flower colour was a light pink, intermediate between the two parents. The F_3 lines showed that there was a very close linkage between the Pink Flower characters (absence of crescent and pink-red corolla). Only two cross-over plants were obtained which had non-crescented leaves (Pink Flower) and white corolla petals (Bacchus Marsh) in a population of about 400 plants in 41 segregating F_3 lines.

Male sterility

Since the (Yarloop x Burnerang) crossbred 705.14.2 appeared to be homozygous for the erect Burnerang gene it was used as a source of this character. F_4 plants from the Yarloop x Burnerang crossbred 705.14.2, were grown for crossing to an earlier maturing strain and it was noted by a technical assistant, Miss J. J. O'Brien, that two plants had no pollen and failed to set seed, except when hand-pollinated. An apparently normal sib plant, 705.14.2.10, was used in crosses with Morocco, but the F_2 comprised 84 normal plants and 21 male steriles, while an F_3 line of the original Yarloop x Burnerang cross, 705.128 gave 107 normal plants to 37 male steriles. These are consistent with the gene being a simple recessive.

When the original (Yarloop x Burnerang) cross was made in 1949 it was not possible to retain the seed and identity of the individual parents of the 1151 heads pollinated. Consequently it is not known whether one of the parent varieties contributed the gene for male sterility.

Male sterility promises to be useful for quantitative studies of natural crossing and it has been found convenient to use it in crosses, even though larger F_2 populations are required, to compensate for the male steriles.

Multiple leaflets

Seed was supplied by Mesrs. Ryan and Elliott of the Western Australian De-

(a) (b)

Figure 5.

Relative winter production (mid-June to early August) in the Avon Valley, Western Australia of Morocco N.1619 and Dwalganup.

partment of Agriculture of a midseason maturing sub-clover which occurs as an admixture in many dry land stands of the Mt. Barker variety, in the Harvey-Brunswick area 100 miles south of Perth. These plants have four or five leaflets per petiole, instead of the normal trifoliate leaf and it appeared that the character would be of value as a gene marker for strain identification, Figure 6.

Crossed with the variety Dwalganup, the F_1 was normal and gave 57 trifoliate-leaf plants to 17 multiple leaf plants in F_2, indicating that the character may be controlled by a single recessive gene. Temperature appears to affect the manifestation of this gene.

Techniques and Equipment

Breeding techniques

Various means of reducing the time-lag in plant breeding have been suggested and are in general use. The principle genetic aid is *back-crossing,* which is being used in the current programme, to transfer the Burnerang-type gene to Morocco.

The back-cross technique is particularly effective when used in conjunction with equipment and methods that will give the maximum number of generations each year. The important devices used in the programme under review are:

(i) *supplementary lighting* to increase the length of day and hasten flowering.

(ii) seed coat removal to shorten the period from flowering to seed maturation and also to avoid delays due to seed dormancy.

The failure of freshly harvested sub-clover seed to germinate has been the subject of considerable research and it has been shown that two factors, dormancy and hard-seededness are involved. In any breeding programme, it is usually desirable to run through the parent (P_1), the F_1 and the F_2 generations in two years and to achieve this, delayed germination must be avoided. The earlier work of H. G. Elliott and Y. Aitken has been reviewed by Loftus Hills (1942) who studied the varieties Mt. Barker, Dwalganup and Tallarook.

Loftus Hills also harvested samples two weeks before maturity, but these failed to germinate immediately owing to mould growth.

It has been found during the current investigations that if the seed is harvested 2-3 weeks before maturity and the coat removed, germination occurs immediately. The seed is placed on sterilised washed building sand and moistened

Figure 6.
Normal Dwalganup leaf (left) and multiple leaflet (right) from cross 1963 (Dwalganup x Four Leaf).

with a boiled nutrient solution, care being taken to maintain the humidity. This technique thus usually means a saving of at least 6-8 weeks between generations.

By using the seed coat removal technique and increased day length, it has been found possible to run through a complete generation of Dwalganup or Geraldton, from seedling to seedling, in fifty-three days.

It has been shown, however, by Aitken (*loc. cit.*), that it is necessary to have low night temperatures, as well as long days, if flowering is to be induced in some strains of sub-clover. For this reason a phytotron, Figure 7, has been constructed at the Institute of Agriculture.

Summary and Discussion

A cross-breeding programme is being undertaken with subterranean clover. This species is well suited to the lateritic sand-plain and red-brown earth type soils which probably account for 75% of the Western Australian wheatbelt.

Early maturing crossbreds have been shown to persist on the lateritic sand-plain soil, even on the drier margin of the wheatbelt, and the emphasis in the breeding programme has shifted to the production of strains which are superior agrostologically.

The Burnerang gene for erect growth habit is being used in an endeavour to break the association between "earliness and stemminess", and to produce strains which will set considerable seed above ground. It is hoped, also, to reduce the amount of woody burr surrounding the seed, as well as increase the yield of seed per acre, so that wheatbelt subterranean

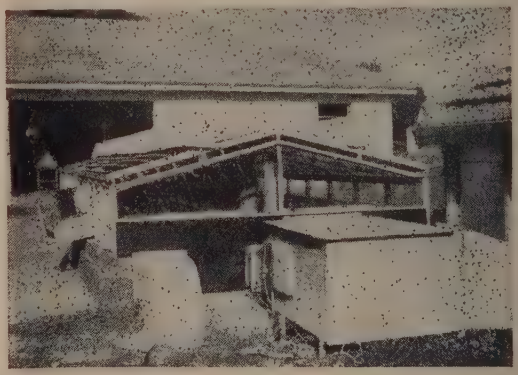

Figure 7.
End view of air conditioned glasshouse, which is equipped with supplementary lighting and adjustable shades for sunlight control.

clover pastures will be more nutritious in the dry state.

The Geraldton strain has been found to mature seed much more rapidly than Dwalganup and is being used in the breeding programme as a source of this characteristic.

Extreme winter vigour is characteristic of some Morocco strains, and a back-crossing programme is being carried out to incorporate this heredity in strains which have better leaf and seed production characteristics.

The characters "Burnerang erect growth habit" and "multiple leaflets" appear to behave as simple recessives and "red leaf" as a simple dominant. These may be of value as strain markers.

Male sterility appears to be controlled by a single recessive gene, while there is a close linkage between the variety Pink Flower characters "absence of leaf crescent and intense pink flower".

Techniques which have been shown to be of value in speeding up the breeding programme are supplementary lighting and coat removal from immature seed. A phytotron has been designed and erected to give controlled night temperatures and increased day length.

Acknowledgment

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REGENERATION OF MARGINAL LANDS IN THE NEW SOUTH WALES WHEAT BELT

By L. G. KALESKI

Introduction

In considering regeneration of marginal lands it is necessary to have in mind what we mean by the term "marginal." For the purposes of this paper, I have in mind those lands upon which a farmer, exercising plenty of hard work and having an average amount of rural knowledge, skill and financial resources, would not earn a good living.

Location

In New South Wales the term "South-West Marginal Wheat Area" was officially used in the nineteen-thirties in connection with the rehabilitation of a large number of landholders who had been settled on light soils of a sandy nature, including mallee soils. These lands were situated in the Western Riverina, between the Murrumbidgee and Lachlan Rivers, between the 13-inch and 15-inch isohyets, and were settled on a basis of the farmer making a living primarily on a wheat-fallow rotation.

Because of low rainfall and wind erosion, average wheat yields during the nineteen-twenties were very low. When wheat prices fell in 1930, this method of land usage became uneconomic; later, farming areas were substantially aggregated to allow grazing to become the major land usage. Today there is very little wheat grown in this area.

In the eastern areas of New South Wales, Davies has referred to many millions of acres of marginal land which may be made highly productive under intensive grassland improvement practice. These lands are mainly in the podsol belt, between the 25" and 50" isohyets. The improvement is envisaged by the use of fertilizers, trace elements, lime, legumes, rhizobium and high quality grasses.

A third group of lands, much of which is or was marginal on the above-mentioned standard, is now described, namely the gully eroded lands within the western slopes of New South Wales, mainly red brown earths between the 16" and 25" isohyets.

Erosion Survey

The Erosion Survey of New South Wales, carried out by the Soil Conservation Service during 1941-43, indicates the following position:—

Area of land within western slopes of N.S.W.	52,000,000 acres
Area of land affected by gully erosion	16,000,000 acres

Acquisition of Soil Conservation Research Stations

In order to study and devise measures to remedy this position, the Soil Conservation Service acquired five Research Stations within the wheat belt during 1940/1946, at Wagga, Cowra, Wellington, Gunnedah and Inverell. Some of the activities on these are now used to illustrate methods of reclamation of marginal lands within the New South Wales wheat belt.

In each case the lands rise from gently sloping, formerly arable lands to steep slopes up to 30% and to cliffs in the case of Gunnedah.

The steep upper lands had in each case been cleared of timber; pastures on these and the intermediate slopes had been

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eaten bare by long continued overstocking, and the depredations of rabbits. Excessive run-off from these higher lands flowed across the lower arable lands, gouging out deep and frequent gullies down every flow line. Because of the removal of huge amounts of topsoil and the physical obstruction of the gullies, the lands had been abandoned for cultivation prior to 1945, and had reverted to sparse weedy pasture.

Research Station Works

Land Use Planning

The method of classification and land use planning as developed in the United States a few years previously, was modified and used in classifying these lands and planning the future soil conservation works.

The classification used was as follows:

A. Land suitable for cultivation.

1. No special soil conservation practices necessary.
2. Simple soil conservation practices, e.g., contour cultivation, adequate rotations, etc.
3. Intensive soil conservation practices, e.g., in addition to (2) above the installation of diversion banks, graded banks, grassed waterways, etc.

B. Land suitable for grazing.

4. Land suitable for sown pasture, too steep for regular arable production, but from which an occasional crop can be taken under protective mechanical measures.
5. Permanent sown pasture on steep slopes permanently protected by absorption or diversion banks and pasture furrows.
6. Very steep, sometimes rocky areas, which can be improved only by broadcasting seed and fertiliser, and on which very limited stocking should be practised.

C. Lands unsuitable for cultivation or grazing.

7. Lands which should be retained under forest or planted to forest, and from which stock should be excluded.
8. Cliffs, lakes, swamps and similar unusable and untreatable land.

Soil Conservation Land Usage.

Having classified the lands the next thing to do was to implement the classification.

It was apparent that practically the whole of the internal fencing on all Stations was unsuitably located. The first soil conservation measure, therefore, was to pull out practically the whole of the internal fencing and re-fence on the contour on a land-use plan basis. Most of the original fencing had already fallen down or was in an otherwise ineffective state, compatible with the severely depreciated state of these lands.

There was no land in Class I, i.e. land requiring no soil conservation measures, on any of the Stations. There were very limited areas in Class II and the main consideration in respect of the arable lands was the Class III Group, i.e. the lands requiring intensive mechanical soil conservation measures.

On all Stations this involved, firstly, massive diversion banks on low grade (0.25% to 0.4%) at about the 8 to 10% slope to intercept any uncontrolled run-off from the higher lands and take it round the slope to dams and/or waterways and lead it to safe disposal areas.

Below these absorption or diversion banks, the gullied Class III arable lands were then treated mechanically by gully filling, graded banking, grassed waterway construction and contour working and sown to the "wheat-subterranean clover ley-fallow" rotation in the south and the "five-year stubble mulch wheat-five year lucerne ley" rotation in the north.

The Class IV lands above these received somewhat similar mechanical treatment, but permanent pastures of lucerne, Phalaris and subterranean clover in the south and lucerne and Rhodes grass in the north were sown. These lands range to about 15% slopes.

FIGURE 1.
Sheet and gully eroded Class III arable lands on Wagga Soil Conservation Research Station in 1945.

FIGURE 2.
An area in the same paddock as Figure 1, under Wimmera rye grass and subterranean clover ley in 1953, after intensive soil conservation practices.

Class V lands, i.e. steep natural pastures, were not ploughed, but intensively pasture furrowed on 1 to 3 feet vertical intervals and Wimmera ryegrass and subterranean clover and superphosphate scarified in the south and Rhodes grass and *Urochloa panicoides* in the north. These lands range up to 30%. On the northern Stations massive level absorption banks were used instead of pasture furrows, because of high intensity summer storm frequencies.

Class VI lands represent the steepest grazing lands on which hand broadcasting fertiliser and perhaps seed is of value on small areas, and aerial topdressing on larger areas. On the Research Stations Class VI lands were limited in extent.

The Class VII lands, i.e. land at present under forest or which should be planted to forest for soil conservation purposes, with stock excluded, were well represented.

The Service is raising 75,000 trees per year in its Station nurseries. In earlier years these trees were mostly used on the Stations and other Crown lands. Existing timber stands, particularly on ridges, were thickened and extended, corners of paddocks formerly severely eroded were planted, shade and shelter belts were established on all boundaries and Station roads and the farm forest was accorded its own particular place of importance in land classification and the implementation of plans for wise land usage on these Research Stations.

Class VIII lands, the cliffs, swamps, etc., were very limited in area.

Results Achieved

Results have been measured in three ways: firstly, by measurement of the changes in the vegetation and decrease in the run-off and soil loss from the areas concerned; secondly, by the production of crops and stock during the decade this work has progressed; and, thirdly, by the impact of this phase of soil conservation work on the rural community as indicated by the extent to which they have undertaken similar work on their own holdings at their own expense.

Vegetation on Hill Lands

At Wagga Station slopes of the hill lands are about 20%, with 30% maxima.

The marginal state of these lands prior to soil conservation development is illustrated by records of permanent quadrats located at random in 1947 throughout the hill lands. Typical quadrat counts are given in Table I.

In Military Paddock the sheet eroded stony ridge was, in 1948, devoid of any vegetation over 90% of its surface area and the sparse vegetation consisted of Stipa and Aristida spp. which are of low forage value. By 1953 this paddock had been reclaimed to the state of complete ground cover by subterranean clover and the low value species had been crowded out.

In Cow Paddock, once cultivated, but abandoned to thin weedy pasture prior to 1945, bare ground was reduced from 62% in 1948 to zero in 1953 and skeleton weed crowded out by a dense pasturage of Wimmera ryegrass and subterranean clover.

Over 100 acres of the steep hills of the Research Station, marginal to a state of having been almost completely unproductive because of erosion, have been similarly transformed from practically bare stony ground to highly productive pastures at present carrying 2 sheep per acre, and with considerable further improvement now possible by the introduction of Phalaris tuberosa at this stage.

Run-Off and Soil Loss From Soil Conserved and Unconserved Catchments

At the southern end of Wagga Soil Conservation Research Station are two small catchment areas, side by side, each of 25 acres and of similar 15 to 20% slopes. One catchment area has been soil conserved by the installation of level pasture furrows at 2 ft. vertical intervals, sown with Wimmera ryegrass and subterranean

FIGURE 3.
The "front" paddock at Wellington Soil Conservation Station in 1945. This area had been abandoned for cultivation purposes.

FIGURE 4.
Restored arable lands on Wellington Soil Conservation Station in 1953, producing high yielding crops eight years after installation of Class III soil conservation measures.

TABLE I.

Typical quadrat counts on hill lands at Wagga Station.

Military Paddock: Quadrat 4W.

	1948	1950	1953
Bare ground	90%	55%	0%
Stipa-Aristida spp.	Sub-dominant	Dominant	Absent
Subterranean clover	Occasional	Present	Dominant

Cow Paddock: Quadrat 4.

	1948	1950	1953
Bare ground	62%	0%	0%
Skeleton weed	25%	Present	Absent
Subterranean clover	2%	Dominant	Dominant
Wimmera ryegrass	4%	Present	Sub-dominant

clover and top-dressed with superphosphate each year since 1950. The other catchment area remains untreated. At the outlet of each a measuring weir and water stage recorder have been installed.

The soil-conserved catchment area is grazed at the rate of 2 sheep per acre as against 1 sheep per acre on the untreated; in 1952 the amount of run-off from the soil-conserved catchment was one-fifteenth that of the untreated catchment, the maximum rate of run-off was one-seventeenth, and the amount of soil lost was a trace as against 10.3 tons from the untreated area. 1952 was the wettest year (26.2 inches) since the installation of the measuring weirs and recorders.

It would be better to retain all or most of our rainfall on the farms, by reclaiming marginal lands by soil conservation farming and grazing land usages; thus the problems of roadside erosion, siltation and flooding could be mitigated at the source of the trouble instead of at the end point.

At Gunnedah in 1946 the mechanical soil conservation works had just been completed on approximately 300 acres of very seriously eroded lands up to 30% slopes. Run-off from these lands previously concentrated at one point in the north-eastern corner of the Station, passed through a railway culvert, across the main north-western highway and spread across the Mooki river flats.

In January, 1947, a storm of 595 points in 90 minutes was recorded. Just prior to Station acquisition, previous storms of much less volume and intensity had twice resulted in run-off which destroyed about 10 chains of railway embankment, road and adjacent lower boundary fence, the run-off being estimated to reach the rate of 500 cusecs, or nearly 2 cusecs per acre.

The installation of the mechanical soil conservation measures so reduced the amount and the rate of run-off, that in this record storm, even though every furrow, bank and waterway flowed to capacity, there was no damage either to Station lands or to railway embankment, road or adjacent lower lands.

Since 1947, the vegetative, as well as the mechanical soil conservation measures, have been installed and there is now seldom any run-off at all.

The water is now practically all absorbed and used in situ for the production of crops and pastures, resulting in high yields on lands which prior to 1946 were saw-toothed with gullies and out of arable production.

Run-Off and Soil Loss Under Different Land Usages

On the steepest section of the arable lands on the Wagga Station (9% slopes) an experiment was laid out in 1948 in plot form to ascertain run-off and soil loss under various forms of land use. Each plot is 132 feet in length, i.e. the normal distance between graded banks on slopes of this nature.

Results from 1948 to June 1955 are as follows:—

Treatment	Run-off Inches	Soil Loss Tons per acre
Wheat-fallow (6 plots)	10.93	9.14
Wheat-ley-fallow (9 plots)	7.37	5.45
Upland lucerne (3 plots)	4.38	0.48
Improved pasture (3 plots)	3.27	0.25

Nearly 50% more water and 70% more soil is lost by farming under the wheat-fallow system than the wheat-ley-fallow. During these seven years also about three times as much water and thirty times as much soil has been lost from land under wheat-fallow than from adjoining land under lucerne or improved pasture.

Pasture Production

The next method of ascertaining the value of land classification and soil conservation farming is to measure stock carried and yields of crops.

On the whole Wagga Soil Conservation Research Station the 550 acres were in such an eroded infertile state that less than half a sheep per acre was carried prior to acquisition and development of the Station in 1945-46. Since 1947 the previous stock carrying capacity of the whole Station has been increased from 0.5 to 2 sheep per acre as follows:—

1948	0.68	sheep per acre.
1949	0.91	„ „ „
1950	1.60	„ „ „
1951	1.90	„ „ „
1952	2.01	„ „ „
1953	2.10	„ „ „
1954	1.70	„ „ „

The slight regression in 1954 was associated with an unusual climatic year.

Annual pasture production on Wagga Station has been at least trebled in quantity and quality in seven years.

At Wellington the story is similar. Most of this 500 acres is arable, but, instead of a three-year rotation of wheat-subterranean clover ley-fallow at this Station, the land usage includes a rotation of six years' wheat-fallow followed by a five-year lucerne ley.

Prior to 1948 the grazing figures were in the vicinity of 0.5 sheep per acre over the whole Station area. Following development in 1946 and 1947 the average grazing rate over the whole Station during the period 1948-54 has been 1.4 sheep per acre and on the lucerne leys, comprising more than a quarter of the Station lands at any one time, the average grazing rate has been 2.58 sheep per acre during 1948-54.

At Wellington as in the case of Wagga it is clear that pasture production has been trebled in seven years on lands which were out of cereal production and marginal for stock because of erosion.

In respect of quality of the pasturage fat stock from both Wagga and Wellington, fed on pasture only, have been regular prize winners at local Agricultural Shows in recent years.

Wheat Yields

At Wagga undulating arable lands were out of production because of sheet and gully erosion. No wheat had been grown for many years. The first crop grown by the Service in 1946, after gully filling and construction of graded banks, waterways and contour cultivation, produced 1.5

bushels per acre. By 1954, in paddock Arable C, yields were available of three crops grown during a period of 9 years on three wheat-subterranean clover ley-fallow rotations. The yields are:—

1948 (following sub. clover ley & fallow in 1946-47), 12 bushels.	
1951 (following sub. clover ley & fallow in 1949-50), 18 bushels.	
1954 (following sub. clover ley & fallow in 1952-53), 30 bushels*.	

(*1954 crop yield is an equivalent, based on a 38 cwt. per acre cut of hay.)

At Wagga Station there is a very interesting sight at present. Some graded banks built of topsoil in 1946 have recently been levelled and the bank lines incorporated in the arable area. The wheat along these old lines is yellow and stunted. On either side the soil which has had the benefit of the protection of the banks and of three subterranean clover ley rotations for nine years is producing a dense vividly green crop, which promises a very high yield for 1955. The yellow spindly crop lines are truly representative of the 1946 marginal condition of the land and will yield practically nothing.

At Wellington the results have been similar. The "Front" paddock of 70 acres, following regular wheat growing without rotation for about 40 years had, by 1945, degenerated into a deeply gullied and sheet eroded scalded area, abandoned for cultivation and so lacking in structure and fertility that even the black oats in 1946 were sparse, spindly and yellow. Mechanical soil conservation measures were installed and the paddock sown to its lucerne ley and heavily fertilised, grazed and renovated for five years. In 1952 the cereal phase of this rotation was commenced in this paddock and wheat was sown. The yield was 42 bushels per acre. There is a similar story on the remainder of the Wellington Research Station lands.

Thus at Wagga and Wellington lands which were marginal, i.e. capable of producing only very low yields of cereal crops in their existing state, because of erosion, have been raised to the highest yielding lands in their respective districts, with yields at least double the New South Wales average.

Adoption of Soil Conservation Land Usage by Farmers

The third method adopted for measuring the value of the land classification, mechanical soil conservation measures and wise land usage adopted on the Soil Conservation Research Stations, is to examine the number of farmers who have followed the lead given and the extent of their work.

In New South Wales as a whole there are 73,000 rural landholders of whom about 35,000 have an erosion problem of some sort. The properties of 13,000 of these landholders have, on request, been inspected at least once by officers of the Soil Conservation Service.

During the last five years more than 4,500 landholders, the total area of whose farms exceeds 6,000,000 acres, have carried out mechanical soil conservation works to the Service's design and 2,500 farmers have hired the Service's plant to do so at cost to them of £500,000. Most of this work is being carried out in the wheat belt within the 16,000,000 acres affected by deep and frequent gullies. Possibly more important than the amount of work that has been completed is the fact that after five years' assessment of the value of this work, at a time when wheat prices are falling heavily, the demand by farmers is still rising sharply. In one only of the Service's twelve Soil Conservation Districts, Riverina, there are at present date 240 outstanding plant hire applications of value exceeding £100,000.

Conclusion

In conclusion I would say it is quite feasible to double the output from crops and stock and farm timber at low capital cost, from all the eroding arable farms in the western slopes of New South Wales by land-use planning and soil conservation farming.

We know this can be done because it *has been* done on so many representative farms from the Victorian to the Queensland border.

And finally, farmers throughout these areas are rapidly becoming aware that in 1955 it is more economical to increase their output 100% by spending £3 or £4 on each existing acre than to buy a new acre at £30 or £40 to achieve the same result.

Acknowledgment

The work of many officers of the Soil Conservation Service stationed on these Research Stations is fully acknowledged.

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BOOK REVIEWS

WARTIME AGRICULTURE IN AUSTRALIA AND NEW ZEALAND

By J. G. CRAWFORD, C. M. DONALD, C. P. DOWSETT, D. B. WILLIAMS and A. A. ROSS

(*Food Research Institute of Stanford University. Oxford University Press,* 1953.—78/9 *Aust.*)

Interest in History seems to vary widely from one individual to another. Some find it unutterably dreary, a few regard it as positively revolting. Personally, I have never been able to understand this last group. Are they merely extreme examples of the fourth of Cornford's University types — "Young-men-in-a-hurry" — lacking all appreciation of the guidance which history can give, if rightly used? Or are they the equivalent in the psychological world of those unfortunate children, who owing to Rh incompatability, find their mothers' protein poisonous? However, I think the majority finds history interesting for its own sake, and of some value as a guide for future thinking and planning when similar circumstances recur. Consequently, this book should have many Australasian readers.

The Australian and the New Zealand developments are necessarily kept quite separate; the differences in political forces and the agricultural environment in the two countries naturally demand this separation. The latter benefits to some extent, because it is the work of a single author, while the former is a composite effort, and in places suffers for that reason.

The book offers a series of surveys of the way in which the war influenced the farming industries through extra demands for certain products, through manpower shortage, loss of supply of materials, and through price policy. It details how the production of Australian farms was allocated to the competing groups—civilians, our fighting forces and those of our allies, and export to the United Kingdom and other areas for which we were responsible. It concludes with two vital chapters—"Wartime Agriculture in Retrospect" and "Post-war Agriculture in Australia."

I enjoyed reading the book, but I found one attitude which turns up here and there in its pages rather irritating. Chapter I gives an assessment of the prewar pattern of Australian agriculture in quantitative terms. It describes the economic problem which the depression of the 1930's set both the farm industries and the various Governments, but it fails to bring into high relief the attitude of mind which the anxieties of the dreary decade of disillusionment—1929-39—engendered in many sections of the farming community. This was particularly important among the rural wage workers, most of whom were not protected by awards—although many farm families were little better off. There was not much satisfaction in a life which required a man and his wife to milk 25 cows twice a day to produce a *gross* farm income which was often less than £200 a year. It was this state of affairs which shook the farm manpower position as soon as the demands of war-time factories with their high wages offered opportunities in the cities. The reaction of the farm industries to many war-time situations was inevitably influenced by this experience.

Many comments of the authors give considerable food for thought. For instance, the New Zealand author suggests there is every indication that fertilizer rationing had the effect of encouraging the practice of top-dressing by farmers who had not top-dressed previously, and of encouraging many farmers to top-dress annually. The emphasis on the way in which mechanisation, on the one hand, and the introduction of labour saving devices and methods on the other defeated the reduction in labour supply, is also informative. Thus, in dairying, machine milking carried the matter one stage, and the cessation of hand stripping completed the economy.

There is quite a measure of comfort for Australian readers in this book. We are so prone to take it for granted that we live in a land of muddle and inefficiency while our relatives across the Tasman bask in a continuous climate of sunshine, order and progress, that it is almost comforting to find that the war-time stories are much the same in both countries.

S. M. WADHAM.

SOME ASPECTS OF LAND SETTLEMENT IN RAIN FOREST AREAS OF NORTH QUEENSLAND

By W. J. S. SLOAN

In the latter half of 1952, as a member of a committee known as the North Queensland Land Enquiry Committee, appointed by the Queensland Government, the opportunity was provided for studying some aspects of land settlement in rain forest areas which were of particular interest to the agriculturist.

Rain forest areas which were given special attention included the Eungella Range at Mackay, the Atherton Tableland and the coastal area between Ingham and Cooktown. One of the main terms of reference was to determine whether certain Crown lands were better suited for forestry or settlement purposes. This required consideration being given to the development of lands which had been thrown open in past years.

Over 95 per cent. of the average annual gross value of primary production of the coastal area from Mackay to Cooktown comes from agricultural industries, with forestry being responsible for less than 5 per cent. The present prosperity and state of development is largely due to the sugar industry which alone provides ample justification for the policy of clearing the tropical rain forests for closer settlement. There have been errors in land management and the production of which the land is capable is not being fully realised in a number of instances. These failures, however, are comparatively negligible against the extensive background of progress which has been made.

Large quantities of valuable cabinet woods are produced in the tropical rain forests. Therefore, before further closer settlement takes place it is essential that thought be given to the reservation of sufficient natural timber and potential timber-bearing resources.

The timber industry of the tropical rain forests has meant a great deal to North Queensland. It will continue to make a valuable contribution to the economic development and stabilisation of this region.

Modern forestry science treats timber trees as a crop. Good soils and good rainfall are required for a fast rate of growth and quick regeneration. Timber is a bulky material and long haulage must be avoided if it is to be marketed at a reasonable price.

While timber supplies are drawn from virgin rain forest, expanding settlement forces the timber man to haul his logs from further and further away. Ease of access and cost of haulage are therefore of real concern. The use of modern machinery and further improvements in mechanisation of the timber industry can be expected, however, to mitigate this problem. The improvements noted in the last 30 years from the bullock wagon to present-day methods are fair grounds for such expectation.

Present Distribution of Rain Forest Lands in North Queensland

The following data shows the present distribution of the land originally covered by rain forests in the area from Ingham to the Daintree River:—

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(a) Alienated or leasehold land	1,304 square miles =	34 per cent.
(b) National Parks	155 square miles =	4 per cent.
(c) State Forests	430 square miles =	11 per cent.
(d) Timber Reserves	1,304 square miles =	34 per cent.
(e) Vacant Crown Land, Rain Forest	640 square miles =	17 per cent.
Total	3,833 square miles =	100 per cent.

It will be noted that of the total area of 3,833 square miles originally covered with rain forest, about 2,530 square miles equivalent to 66 per cent. still remain under Crown control as National Parks, State Forests, Timber Reserves and vacant Crown land. It is estimated that of these 2,530 square miles, about 250 square miles or 10 per cent. only will prove suitable for settlement under present-day conditions, leaving 60 per cent. of the original rain forest areas under Crown control and, as far as can be gauged now, in perpetuity.

Deterioration of Rain Forest Lands Following Settlement

Lands in the rain forest areas are attractive for settlement, firstly, because land on which there has been a heavy growth of rain forest is usually very fertile, at least in the early years, and secondly, because of the bounteous summer rainfall. High yields can be obtained from suitable crops on arable lands, while dairying and cattle fattening on pastures sown on burnt scrub land can return satisfactory profits.

Much of the land in these areas is well drained and is easily worked with agricultural implements. Droughts do occur but are usually of short duration and complete crop failures or heavy losses of stock from fodder shortage are seldom encountered. From the point of view of the stock owner, the abundance of supplies of good water is a distinct advantage. Internal and external stock pests are probably more acute than in drier areas but can be combated.

Nevertheless, the question of deterioration of land following the clearing of tropical rain forests merits close examination. In general, deterioration of land is an accusation which can be levelled with some justice against almost any agricultural district where a percentage of inefficient settlers is encountered.

The subject of deterioration of rain forest lands following settlement is discussed under two broad headings, namely, I. Deterioration of soil fertility, and II. Weed problems.

I. Deterioration of Soil Fertility

(a) Crop Lands.—There is no doubt that soil fertility of rain forest lands deteriorates after the scrub is fallen and burnt, but this loss is not peculiar to rain forest areas. Few agricultural districts in Australia have not deteriorated through cropping or grazing where no effort has been made to maintain or improve soil structure and to return plant nutrients to the soil either by crop rotation, pasture improvement, or fertilizing, or by a combination of these methods.

Loss of fertility in lands of the high rainfall areas appears to continue until a certain point is reached beyond which further deterioration is very slow. The sugar-growing industry has shown that suitable varieties, correct fertilizing, good crop management and control of pests and diseases can offset the loss of soil fertility which follows eradication of the rain forest, and cultivation of the land. The sugar growers of this region have adopted wholeheartedly improved methods of production requiring annual usage of fertilizer and expenditure on methods of pest and disease control.

That the sugar-cane grower has met and overcome the problem of loss of soil

fertility in a competent and effective manner is well illustrated by the fact that sugar-cane crops today yield better than those which were grown in the early days of settlement. Yield data for the rain forest areas between Ingham and Mossman which are now under cane are shown in Table I.

TABLE I.
Ingham to Mossman area.

Period.	Average yield of cane per acre per year.	Average yield of sugar per acre.
	tons	tons
1902-1927	17.47	2.20
1928	19.82	2.71
1929-1933	20.82	3.01
1934-1938	21.80	3.12
1939-1943	20.21	2.93
1944-1948	20.59	2.96
1949-1953	24.82	3.44

Not only has there been an increase in the tonnage of green cane harvested per acre, but there has been a pronounced increase in the tonnage of sugar obtained per acre. Although agricultural practices have played a dominant role in this satisfactory state of affairs, mill engineers by improving extraction processes in the mill have also contributed a significant part in the increase of sugar milled per acre.

The situation is less encouraging in the case of the maize growers of the Atherton Tableland. This district still maintains the highest yield of maize grown per acre for unirrigated maize in the State, but production per acre is not as good as it used to be in the early days of settlement. The downward trend in grain yields is shown in Table II.

TABLE II.
Maize grain yields on the Atherton Tableland.

Period.	Average area sown each year.	Average yield of grain.
	acres	bushels per acre.
1924-25 to 1928-29	17,951	37.3
1929-30 to 1933-34	18,299	37.4
1934-35 to 1938-39	20,992	32.0
1939-40 to 1943-44	19,724	26.2
1944-45 to 1948-49	22,151	28.6
1949-50 to 1953-54	24,206	29.8

These figures are in sharp contrast to the achievements of the sugar growers. It will be noted that the period 1939 to 1944 has the lowest average yield of grain per acre and that the yield has shown a definite upward trend since then. It is very probable that the more extensive use of peanuts on maize lands and the fact that the additional land brought under cultivation for maize in the last ten years is land which has not previously been cultivated intensively, account for this slight improvement.

Factors which appear to have influenced the poorer performance of the maize grower compared to the sugar grower are:—

1. There has been little improvement in maize varieties on the Atherton Tableland compared to the major improvement in sugar varieties.
2. The maize grower prepares land annually for his crop while the sugar grower does not have to prepare land for planting more than once every four years. Hence the maize soil is much more exposed to soil deteriorating agencies.
3. The maize grower as yet uses little or no fertilizer, in sharp contrast to the sugar grower.
4. Unstable markets.

It is believed that the maize grower could improve yields by better methods of land management and fertilizer usage, especially nitrogen, but the economics of this procedure are not so well defined as they are in the case of the sugar grower. For instance, the maize yield can be improved by including a green manure crop in rotation with the maize, but the grower finds that it is more profitable to grow maize each year on the same land rather than insert a green manure crop and so lose one season of maize. The inclusion of peanuts in rotation with maize has been shown to be worthwhile and there are indications that Tableland maize growers are interested to use this crop more freely.

Fertilizer applications for maize on the rain forest soils of the Atherton Tableland do not give consistently payable returns. With a dry spring and a dry early summer, nitrate accumulation in the scrub soil appears to be adequate to meet crop demands. On the other hand, if, as happens not infrequently, leaching rains fall during this period, applications of sulphate of ammonia will benefit the maize yield. On the forest soils nitrogen is also the main deficiency, although phosphorus may be lacking as well. In most seasons on forest soils maize crops could be expected to benefit from applications of nitrogenous fertilizers.

Although little improvement has been effected in Atherton Tableland maize varieties except by selection of Dent strains by local growers, it is not inconceivable that ultimately a hybrid maize will be developed which will prove clearly superior to the local Dent and Durum strains.

Cultivation of lands with more than a 6 per cent. slope in high rainfall areas introduces the serious hazard of soil erosion. Nevertheless it is surprising to note in the rain forest areas that erosion is much less than might be expected. The rapidity with which vegetation grows in this region and provides ground cover no doubt assists materially in checking and repairing the damage caused by soil erosion.

Some small steeply sloping areas in the cane growing districts have suffered erosion to such an extent that the paddocks involved have been abandoned. Overall the percentage of land thus affected is low and it is unlikely that any expansion of sugar growing will take place in the future on lands which are too steep for cultivation.

Soil erosion is serious in some maize fields of the Atherton Tableland but soil conservationists have shown that it is practicable to prevent it if correct procedures are followed.

(b) Pastures. — On land which has been sown down to grasses there is very clear evidence that the pastures and hence the stock carrying capacity have deteriorated very considerably. As pasture problems are of more than passing interest, the situation on the Atherton Tableland is described here in some detail.

Dairying on the Tableland was first carried out by a few settlers with station-bred cattle on the forest land near Tolga about the year 1887. Later on, the scrub lands of the Tableland proper were fallen and burnt and initially brought into production by Chinese for maize growing. But in the year 1907 consideration was given to the suitability of these lands for dairying and in that year the Golden Grove butter factory was built in Atherton.

During 1909, the Department of Public Lands opened for Agricultural Farm Selection under the group system, 131 portions in the Atherton district, comprising 22,366 acres, and 49 portions in the Herberton district comprising 10,272 acres. In the following year a further 197 portions in the Atherton district comprising 30,494 acres, and 84 portions in the Herberton district, comprising 17,784 acres were opened for selection on similar terms.

These settlers developed the district rapidly and dairy farming became an important industry. As the demand for land increased the settlement extended to the scrub lands near Ravenshoe and Millaa Millaa. Butter factories now operate at both these centres as well as at Malanda.

Thus the oldest established pastures on the Tableland are not yet 50 years of age.

In the early days of pasture establishment and indeed on pastures sown on newly felled land in these areas today, a stocking capacity as good as one beast to the acre has been claimed.

In the Report of the Royal Commission on the Development of North Queensland (Land Settlement and Forestry) of 1931, carrying capacity was generally accepted as being one cow to two acres for the Tableland scrub country and returns from the dairying industry were compiled on that basis for presentation in the report.

Straughan (1947), in a survey of the Atherton Tableland settlement problem, stated that the carrying capacity on the red loams of the Malanda area would normally be a beast to 4 acres, except on the shallower and poorer clay loams and on steep slopes where the carrying capacity would not be better than a beast to 5 acres. In the younger area of Millaa Millaa he stated that the district's carrying capacity was generally higher than at Malanda, being a beast to 4 acres and in special instances as high as a beast to 3 acres.

During the inspections of 1952 it was apparent that the general carrying capacity was not better than a beast to 4 or 5 acres, except in such instances where land had been fallen and grassed recently, where of course carrying capacity was much improved.

It is quite clear that there has been a steady decline in the carrying capacity of pastures on the Atherton Tableland. It is not improbable that the older pastures have now reached a level below which there is not likely to be appreciable deterioration, provided that growth of weeds such as lantana (*Lantana camara* L.) and wild tobacco-tree (*Solanum auriculatum* Ait.) and similar pests is kept effectively in check.

The opinion has been expressed from time to time that better pasture management in the form of lighter stocking in the early days would have prevented much pasture deterioration (apart from weed infestation). This contention, however, is open to doubt. The removal of the forest canopy exposed the soil to the heavy rains and greatly increased leaching, even though a good ground cover of grass existed.

Lighter stocking may have slowed down the rate of deterioration but eventually the pastures would have reached the condition of the more heavily stocked pastures, simply because of the high rainfall and the leaching of plant nutrients. The condition of the pastures would probably not have been any better today even if lighter stocking rates had been used by the settlers in the early days of pasture establishment. In actual fact it would appear to be desirable to use the prolific growth of the early years to the maximum, providing that the control of annual and perennial weeds and scrub regrowth is not neglected and ample cover is maintained by the pasture.

The deterioration of pastures of the Atherton Tableland can be explained simply as being due primarily to a lack of nitrogen. The main pasture of the dairying industry on the Tableland is *Paspalum dilatatum* Poir. Kikuyu (*Pennisetum clandestinum* Hochst.) has also been used there for many years and a large percentage of the farms now have paddocks of this grass.

The most serious problem is the absence of a suitable legume component. It is true that white clover (*Trifolium repens* L.) grows on the Tableland and in some years in some favoured districts growth is prolific but this state of affairs is exceptional and not the rule.

There is only a limited future for Tableland pastures if dependence has to be placed on a winter growing legume such as white clover. Investigations are in progress to find a summer growing legume and if the promising lead found already (*Glycine javanica* L.) fulfils expectations it may change the picture.

The only alternatives are to initiate a cropping routine in which pastures are a phase, or resort to applications of soil amendments and fertilizers or a combination of both methods. On many farms it would be impossible to cultivate

large areas because of the steep slopes. In these circumstances periodic light renovation combined with fertilizer applications appears to be the only way to raise productivity. On present indications it would seem that, if the output of pastures on the Atherton Tableland is to be improved materially, then the use of fertilizers, especially nitrogenous types, is necessary.

The position is more serious on the Eungella Range country where the soil is of a lower level of fertility and the pasture land on the average more steeply sloping than on the Atherton Tableland. There is, however, scope for the use of soil amendments, fertilizers and renovation, but the economics of these practices remain to be determined.

On the tropical coastland region between Ingham and Cooktown the pasture position is more satisfactory because a legume component can be recommended with confidence. *Centrosema pubescens* Benth. combines well with Guinea grass (*Panicum maximum* Jacq.) and also with para grass (*Brachiaria mutica* (Forsk.) Stapf) on the moister low-lying country. *Stylosanthes gracilis* H.B.K. has also shown distinct promise for use in the lower rainfall areas of this region. In general, the establishment and maintenance of pastures can be approached with more confidence on the coastal country than on the highlands.

Some erosion has occurred on steep grasslands in the form of slips which can be seen in the Millaa Millaa and Eungella districts. Similar slips do occur even under virgin rain forest. No doubt these will eventually stabilize under grass. Cattle tracks are liable to wash but as mentioned previously the rapidity with which vegetation grows and covers bare patches prevents the extensive development of bad gullies.

II. Weed Problems

That excessive weed growth is a real menace in high rainfall areas needs no emphasis. In cultivations, constant care and attention are required to reduce weed competition with the crop plants. The success of sugar and maize crops, however, is evidence that cultivators can meet the problem. It is not unlikely that, in future, weedicides may make weed control less difficult than it now is.

Although growth is more rapid and prolific on the rain forest lands, in general, weeds do not pose any special problems on cultivations, other than the fact that rainfall restricts the use of implements. This latter effect is well illustrated in maize crops on the Atherton Tableland where a dense growth of weeds develops as the crop matures, a sight which often leads visitors to criticize severely the maize growers. Control of this weed growth, by implements anyway, is not easy because when the wet sets in, cultivation is prevented.

In sharp contrast, the situation with weeds in pastures is much less satisfactory. The most serious weeds are lantana, wild tobacco-tree, blady grass (*Imperata cylindrica* var. *major* C. E. Hubbard), narrow leafed carpet grass (*Axonopus affinis* Chase), sour grass (*Paspalum conjugatum* Berg.) and bracken fern (*Pteridium aquilinum* L. Kuhn). There are many others such as inkweed (*Phytolacca octandra* L.), Brazilian fire-weed (*Erectites valerianifolia* DC.), Commonwealth weed (*Erectites atkinsoniae* F. Muell.) and several species of Solanaceous weeds which grow prolifically on burnt scrub land but which dwindle rapidly in importance with the age of the pasture. Regrowth of scrub species of trees and undergrowth also has to be watched carefully, although it is advisable to retain some for shade purposes and for protection against soil erosion along creek banks.

Far too many pasture paddocks in the tropical rain forest areas are infested with lantana, wild tobacco-tree, bracken fern or blady grass. These species if unchecked will ultimately smother paspalum pasture completely. Control can be obtained by brushing, mowing or bruising

with or without weedicides, and the pasture re-established by oversowing. Sometimes, burning may also be required.

With these weeds the managerial capacity of the farmer and the energy with which he approaches control measures are the key factors. These factors, more than any other, need to be given fullest expression in the opening up of rain forest lands. It is most important that the new settler does not fall more scrub than he can comfortably handle and it is equally important that he establish and maintain good control of weeds and scrub regrowth on the sown pastures before he falls large additional areas of rain forest.

Pastures in these areas can be stocked in about six months after the seed has germinated. The stocking rate should not exceed that which will allow the ground to be left well covered with pasture, otherwise the growth of perennial and annual weeds is encouraged. Provided weed growth is effectively checked there appears to be no objection to stocking the pasture as heavily as circumstances will permit as soon as the new pasture has made good growth.

The most serious weeds of the pastures are narrow-leaf carpet grass and sour grass. Solutions to these plant problems have not yet been found. Good grazing management involving the subdivision of paddocks and the avoidance of over-stocking, ploughing and sowing to crops before resowing to pasture; lighter renovation and the use of soil amendments and fertilizers all offer scope for investigation, but there is no certainty of a ready solution at least on the steeply sloping lands. Perhaps circumstances may force recognition of the weed grass species as the pasture species and study will then be needed to improve the productive capacity of the former weed species.

There is one point requiring explanation in connection with weeds in the tropical rain forests. The growth of weeds and of secondary scrub species may reduce the attractiveness of the landscape; it may in some instances make clearing more difficult than in the original state. It does not follow, however, that the soil itself is ruined, because the thick carpet of vegetation protects it and commences the process of rebuilding the soil fertility.

For instance, perhaps the commonest regrowth on cleared rain forest areas is lantana. Soil fertility definitely improves under cover of this species and with modern methods of clearing, its removal and the re-establishment of grass is by no means an insuperable problem.

Neglected farms overrun with weeds can be expected in most settlements. Restoration of production from such farms is certain to follow population pressure, provided such farms do offer reasonable prospects of ultimate profitable development.

Conclusions

A reliable summer rainfall, excellent supplies of water, and good road and rail transport facilities are very great advantages for settlement of rain forest lands north of Townsville.

Despite failures in a few districts there is no doubt that settlement of rain forest areas in northern Queensland has been successful. This success has been most advantageous not only to Queensland but also to Australia, because it has meant the establishment of thriving rural and industrial centres of population in northern regions.

In the agricultural industries there are problems but, except on steeply sloping land, they do not appear to offer greater difficulties than are to be found in most other agricultural areas. The problems of pasture establishment and of management to maintain high production per acre are those requiring most intensive investigation.

It is true that too many acres of land once covered with rain forest and then

fallen, burnt and sown to pasture, are now badly infested with weeds, a very prominent species being lantana. On the other hand, there are tens of thousands of acres which are making a very valuable contribution to food production and to the economy of Queensland. Also, much of the weed infested land can be reclaimed for pastures and brought into production again.

Treatment of steeply sloping pasture lands in the rain forest areas can hardly be viewed with confidence at the present juncture. But, with improvements in machinery and the continued advance of agricultural science, it is not unlikely that a satisfactory solution will be found.

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BOOK REVIEWS

PRINCIPLES OF FARM MACHINERY

By ROY BAINER, R. A. KEPNER and E. L. BARGER

(*The Ferguson Foundation Agricultural Engineering Series*: *John Wiley & Sons*, 1955. P. 751. $8.75.)

The first really comprehensive book specifically produced for agricultural engineers engaged in the design of farm machines. It contains a wealth of detail, in some cases including what would appear to be unnecessary formulae.

The layout and format of the book is very good and an excellent list of references at the end of each chapter leaves little to be desired, while set problems make it very suitable for students doing the course in agricultural engineering.

Choice of nomenclature is generally very good and could well be the basis for general standardisation of terms but the inclusion of A.S.A.E. accepted and proposed Standards appears to be redundant.

The book fills a long-felt want in bringing together our current knowledge of the subject and shows how little we really know of the fundamentals involved, and how haphazard has been the progress in the past; and it does clearly indicate directions along which future progress should proceed and where advances are likely to be most advantageous, as for example the advantages of rotary cultivation, flame weeding and the need for a new method of mowing standing crops.

Some of the machines discussed are not as yet widely known in Australia and some appear to have little application here but the detailed presentation of those machines we do know makes the book quite valuable since it is to be remembered that the book is produced for engineers and they are the ones most likely to benefit from it.

The subject matter starts with a brief historic approach, discusses the capacities and costs of machines, the material used in their construction, then proceeds chapter by chapter to group the different machines under their cultural use, for example, tillage, planting, fertilising, harvesting, pest control, transport, etc. The illustrations, graphs, charts and tables are plentiful, clear and to the point and make the book easy to read and very useful for reference.

ALAN W. BYRNES.

COMPETITION BETWEEN STRAINS OF *RHIZOBIUM TRIFOLII* IN PEAT AND BROTH CULTURE

By K. C. MARSHALL

Summary

Studies on the competition between strains of root-nodule bacteria using the technique of serological typing indicate that some strains may almost completely dominate others when they are grown together in either broth or peat. The practical implications of this finding in the commercial peat culture industry are discussed. Of the strains studied NA30 was found to be a consistently poor competitor in both broth and peat culture.

Introduction

In the American peat culture industry the standard practice is to grow a number of strains of root-nodule bacteria together in broth and then to use this broth culture to prepare peat cultures. The strains used are all capable of effectively nodulating the legume for which the inoculum is intended. As the cultures are used over a wide range of soil and climatic conditions it is hoped that the incorporation of a number of strains will provide a satisfactory inoculum for most situations encountered. Following the introduction of commercial peat inoculants in Australia some firms have been preparing mixed cultures by growing a number of strains separately in broth culture then mixing them in the peat. In view of the lack of information on the behaviour of strains in mixed culture it seemed desirable to investigate the competition between a number of strains of *Rhizobium trifolii* in both broth and peat culture.

The strains of most importance in mixed culture production in New South Wales are as follows:—

White clover (*Trifolium repens* L) group—strains NA30 and SU204.

Subterranean clover (*T. subterranean* L.) group—strains NA30, SU297 and SU298.

The origin of each strain is given below:—

Strain NA30—N.S.W. Dept. of Agriculture strain from sub-clover.

Strain SU204 — Sydney University strain (ex "Clover F", Rothamsted).

Strain SU297 — Sydney University strain from crimson clover.

Strain SU298 — Sydney University strain from crimson clover.

Experimental

Two series of 5 cultures were prepared using yeast mannitol broth, the first being a mixture of NA30 and SU204 and the second a mixture of NA30, SU297 and SU298. Approximately equal numbers of each strain were used to inoculate the broths, namely:—

Mixed culture A	NA30 = 14 viable cells/10 mls. broth. SU204 = 23 viable cells/10 mls. broth.
Mixed culture B	NA30 = 3 viable cells/10 mls. broth. SU297 = 10 viable cells/10 mls. broth. SU298 = 8 viable cells/10 mls. broth.

Viable counts of the broths were made after 4 days incubation at 26°C. To obtain an estimate of the proportion of each strain in the cultures 20 colonies were

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TABLE I.

Number of rhizobia added per gram of peat ($x 10^6$).

	Strain	Method of broth culture	No. of cells of individual strains	Total No. of cells
Series 1	NA30 SU204	Grown singly	21 36	57
Series 2	NA30 SU204	Grown together		141
Series 3	NA30 SU204	As for series 1 but U.S.A. peat used.		
Series 4	NA30 SU297 SU298	Grown singly	14 17 38	69
Series 5	NA30 SU297 SU298	Grown together		54

selected at random from each plate and tested serologically against the appropriate antisera using the method described by Vincent and Waters (1953).

To determine the competitive ability of the strains in peat a series of cultures were prepared as follows:—

(a) Strains were grown separately in broth culture then mixed and added to the peat.

(b) Strains were grown as a mixture in broth and then added to the peat. Each culture was prepared by adding 9 mls. of broth to 18 gms. of autoclaved peat. The actual numbers of bacteria added per gram of peat are given in Table I. Australian peat was used for most of the cultures, but one series was prepared with peat from the U.S.A.

Counts of the peat cultures were made at 4, 12 and 42 days after inoculation with the broth cultures. On each occasion 20 colonies were selected from each series for serological typing.

Results

The counts of the broth cultures after 4 days' incubation (Table II) show that the growth rate within each series was quite uniform. The results of the serological typing of the isolates from the broths (Table III) serve as an indication

TABLE II.

Number of rhizobia/ml. of broth culture after 4 days at 26°C. ($x 10^6$).

Broth No.	Mixed Culture A (NA30+SU204)	Mixed Culture B (NA30 + SU297 + SU298)
1	92	24
2	98	20
3	81	11
4	127	19
5	110	*

*One tube broken. No count obtained.

TABLE III.

Number of isolates from broth cultures identified serologically as either NA30, SU204, SU297 or SU298.

Broth No.	Mixed Culture A		Mixed Culture B		
	NA30	SU204	NA30	SU297	SU298
1	3	17	1	3	16
2	0	20	0	0	20
3	1	19	1	4	15
4	1	19	1	3	16
5	0	20			
Total	5	95	3	10	67

of the proportion of each strain in the broths. Obviously in a culture containing a mixture of NA30 and SU204 the latter almost completely dominates NA30, whilst SU298 is dominant in a broth prepared by mixing NA30, SU297 and SU298.

An appreciable increase in the number of rhizobia was evident following the addition of the broth culture to the peat (Table IV). This is in agreement with the findings of Lockhead and Thexton (1947) who considered that the increase was due in part to the presence of growth promoting substances in the peat. As a result of this multiplication in the peat it is quite reasonable to expect one or more strains in a mixed culture to become dominant. The results presented in Table V show this to be true. Regardless of the manner in which the strains were cultivated in broth before addition to the peat, SU204 almost completely dominated NA30 and SU298 is vastly superior to NA30 and SU297. These results are consistent with the performance of the strains in broth culture. There was no significant alteration of the balance between strains after 42 days' incubation of the cultures.

The type of peat used does not appear to influence the competition between strains. A possible explanation for the higher number of rhizobia in the U.S.A. peat, particularly after 42 days, is that the peat appeared to have better moisture retention properties than the Australian peat.

TABLE IV.

Number of rhizobia/gm. peat ($x\ 10^6$) after incubation at 26°C.

	Time of incubation			
	0 days	5 days	12 days	42 days
Series 1 . . .	57	2230	840	360
Series 2 . . .	141	1310	680	130
Series 3 . . .	57	3020	2350	1235
Series 4 . . .	69	1090	1400	201
Series 5 . . .	54	1290	760	109

TABLE V.

Percentage of isolates from peat identified serologically as either NA30, SU204, SU297 or SU298.

Series	Strain	Proportion of each strain in the cultures at		
		5 days	12 days	42 days
1	NA30	10	0	20
	SU204	90	100	80
2	NA30	5	0	15
	SU204	95	100	85
3	NA30	5	5	5
	SU204	95	95	95
4	NA30	0	0	0
	SU297	5	5	0
	SU298	95	95	100
5	NA30	5	0	0
	SU297	15	0	5
	SU298	80	100	95

Discussion

The incorporation of a number of strains of root-nodule bacteria with proven field performance into peat cultures for legume inoculation appears to be a sound practice chiefly as a means of providing suitable strains for most soil and climatic conditions. But the results presented above demonstrate quite definitely that some strains are capable of almost completely dominating other strains when they are grown together either in broth or peat culture. This could be a disadvantage under certain field conditions where one of the poorly competitive strains would prove superior to the dominant strain if sufficient numbers of this strain were present. For example NA30 and SU298 have been found to have good field performance on most varieties of subterranean clover but Waters (personal communication) has shown in Lismore red-loam soils that NA30 is superior to SU298 on the Yarloop variety of subterranean clover. Although it would seem desirable to mix these two strains in peat culture the fact that SU298 would almost completely dominate NA30 could possibly result in poorer nodulation of Yarloop than if a pure culture of NA30 was used. On the other hand, the finding of Vincent and

Waters (1953) that the proportions of strains found in the nodules were unrelated to their representation in the root's environment would tend to discount the above statement. Where such a mixed culture is used to inoculate seed which is subsequently sown into a soil that is not conducive to the multiplication of the bacteria, it is possible that the poorly competitive strain would die out before infecting the plant. Serological typing of nodules from plants inoculated with these peat cultures in laboratory and field trials would provide a definite answer to this question.

The original aim of multiple strain peat cultures might be achieved if this dominance of one or more strains in the mixture could be overcome. In the present study the peat was inoculated with broth to give an initial count of 10^7 viable rhizobia/gm. of peat. Subsequent multiplication in the peat increased this figure to about 10^9 organisms/gm. Obviously this multiplication allows a strongly competitive strain to almost completely dominate the other strains in the mixture. Recent investigations by Waters (published elsewhere in this issue of this Journal) indicate that when the peat is seeded with a heavier inoculum to achieve an initial count of up to 10^9 rhizobia/gm. little multiplication takes place in the peat and the balance between strains after a period of incubation is more favourable. If the commercial manufacturer can achieve this high initial count in the peat then the competition factor may be overcome to some extent. A more favourable balance between strains may also be achieved by inoculating separate batches of peat with single strains and allowing a period for multiplication of the organisms in the peat before the batches are mixed. In this way subsequent multiplication should be reduced to a minimum thereby preventing competition between the strains.

A striking feature of the results presented is the consistently poor performance of NA30 in competition with the other strains employed in the tests. This strain has been distributed by the N.S.W. Department of Agriculture for some years with good results under quite a range of soil and climatic conditions. But due to the poor competitive ability of this strain in peat it would seem desirable to eliminate it from any mixed strain peat cultures produced by the present manufacturing technique.

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NODULATION TESTS WITH MIXED INOCULANTS

In view of Marshall's results (published elsewhere in this issue of this Journal), with mixed cultures grown in broth and peat, it may be interesting to note our own experience in laboratory and field trials.

Experiments were carried out during 1954-55 using three strains of root-nodule bacteria, SU36, SU298 and NA30, grown separately and then mixed immediately before preparing the peat cultures.

The number of rhizobia added per gram of peat was as follows:—

Strain	No. of cells of individual strain	Total No. of cells
SU36	4×10^7	
SU298	24×10^7	52×10^7
NA30	24×10^7	

The number of rhizobia after storage of the peat from one day to four months varied between 73×10^7 per gram and 4×10^7 per gram.

At the same time as counts were made colonies were isolated for serological typing. In addition the same peats were used to inoculate Yarloop and Bacchus Marsh subterranean clover sown in the field at Lismore. Subsequently nodules were isolated from these plants for serological typing.

The proportion of the three strains identified from the peat and the two hosts is given in Table I. All three strains were represented at each time in isolations obtained directly from peat with the proportion of SU298 increasing with length of storage and NA30 decreasing.

TABLE I.

The serological identification of isolates from a peat inoculant containing the strains SU36, SU298 and NA30 and of isolates from nodules produced by the peat inoculant.*

Strain	Percentage of each strain from the following:								
	Peat stored	Nodules		Peat stored	Nodules		Peat stored	Nodules	
	1 month	Yarloop	Bacchus Marsh	2 months	Yarloop	Bacchus Marsh	4 months	Yarloop	Bacchus Marsh
SU36	43	49	48	51	42	56	35	17	24
SU298	36	12	25	36	6	22	50	8	29
NA30	15	39	27	10	52	22	11	75	47
Total number of determinations ..	70	65	79	75	36	36	74	58	72
% effectively nodulated plants		96	98		100	100		85	80

The percentage of effectively nodulated plants in control plots was 16% Yarloop and 26% Bacchus Marsh. The effective nodules were identified in the following proportions and apparently for the most part represent cross infection from treated rows. . . .

	Yarloop	Bacchus Marsh
SU36	38%	20%
SU298	47%	70%
NA30	15%	10%

*Serological typing was restricted to effective nodules.

However, this trend is not reflected in isolations from nodules. The proportion of strains varied with the host so that NA30 formed a much larger percentage of the nodules on Yarloop than on Bacchus Marsh.

The results indicate that so long as there is little opportunity for growth in mixed peat cultures, in contrast to Marshall's results where appreciable increase in numbers occurred, one strain will not completely dominate the population. The relative proportion of strains obtained directly from the peat need give no indication of their field performance. In addition where these peats are used as field inoculants the particular host is likely to exert a most important influence in determining the balance between strains forming the nodules.

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BASIC SUPERPHOSPHATE pH CHANGES IN AQUEOUS SUSPENSIONS

It has been observed that on many acid soils successful stands of clover cannot be readily established even when sufficient fertilizer and inoculum have been used. The main cause seems to be poor nodulation of the plants, possibly due to:—(1) The acid content of the soil being detrimental to the survival of the Rhizobium bacteria and (2) when the inoculated seed is sown in direct contact with superphosphate, the highly acid nature of the superphosphate (pH 2.7-3.0) lowers the Rhizobial population markedly (Reid, 1930).

These problems have been overcome to some extent by the addition of lime to the soil, sowing of inoculated seed separately to superphosphate application, and the lowering of the acid content of superphosphate by the addition of suitable alkaline materials such as carbonate (Reid, 1930), hydrate or oxide of lime and more recently ammonia (Loneragan, *et al.* 1955a). Another approach has been the pelleting of the clover seeds with lime prior to sowing (Loneragan, *et al.* 1955b).

This note is primarily concerned with the pH changes that take place in an aqueous suspension of various "Basic Superphosphate" mixes and their possible detrimental effect in converting the "available" phosphate to "unavailable" forms.

Experimental

Small batches of "Basic Superphosphate" were prepared using complete ranges of the following alkaline compounds:—agricultural lime ($CaCO_3$); magnesite ($MgCO_3$); Dolomite ($CaMg(CO_3)_2$); hydrated lime ($Ca(OH)_2$); quick lime (CaO); sodium carbonate (anhydrous) and sodium hydroxide.

Twenty-gram samples of the freshly prepared "Basic Superphosphates" and 100 ml. distilled water were mixed and the pH determined immediately and at periods of up to 60 days. Evaporated water was replaced and contents stirred at frequent intervals.

The results showed that the alkaline compounds can be divided into three groups:—

Group 1: Agricultural lime, magnesite and dolomite. Typical curves for calcium carbonate are shown in Figure 1. It will be noted that the over-

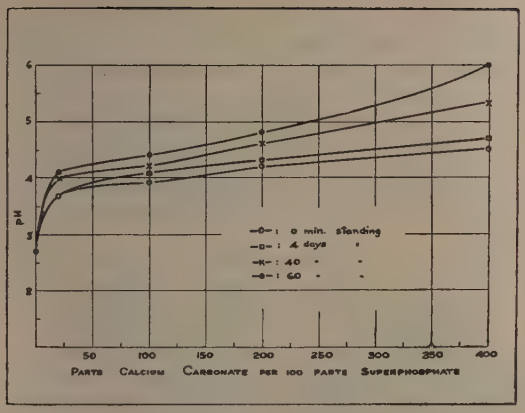

Figure 1.

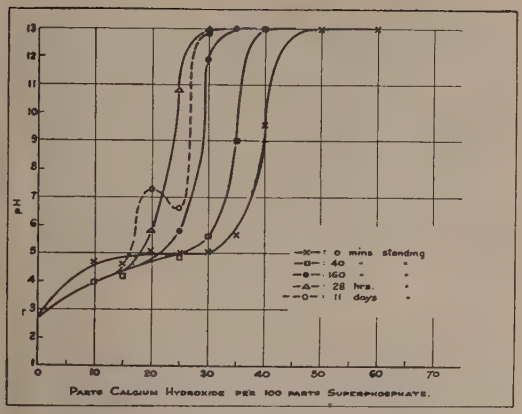

Figure 2.

all increase in pH is rather small and alkaline conditions were not obtained even at the ratio 4:1 carbonate to superphosphate. There is a slight increase in pH of any one mix with time.

Group 2: Hydrated and Quick Lime. Typical curves for hydrated lime are shown in Figure 2. High alkaline conditions can be obtained if an excessive quantity is used. The pH of any one mix rises rapidly during the first few hours; however, on longer standing (11 days), a point of maximum is formed at approximately pH 7.

Group 3: Sodium carbonate and sodium hydroxide. Typical curves for sodium carbonate (anhydrous) are shown in Figure 3. High pH readings are obtainable with an excess of the alkali. The fall in pH of any one mix is rapid during the first few hours, and after several days a point of maximum is formed at a pH of approximately 7.

Phosphate Fixation

There is a real possibility of part of the "available phosphate" in the superphosphate being converted to "unavailable" forms in these "Basic Superphosphates", especially in the case of Group 2 compounds where it would be expected (even if the overall pH as determined in aqueous suspensions is satisfactory) that localized areas of high pH adjacent to the hydroxide or oxide particles would develop. These areas of high pH would increase the chances of "unavailable" forms of phosphate being produced.

The conversion of "available" to "unavailable" forms could proceed along the following lines:—

$$Ca(H_2PO_4)_2 \longrightarrow CaHPO_4 \longrightarrow Ca_3PO_4 \longrightarrow \text{(higher basic phosphate compounds)}$$

alkaline conditions favouring the formation of compounds to the right. This series also corresponds roughly with the decrease in availability. Therefore it

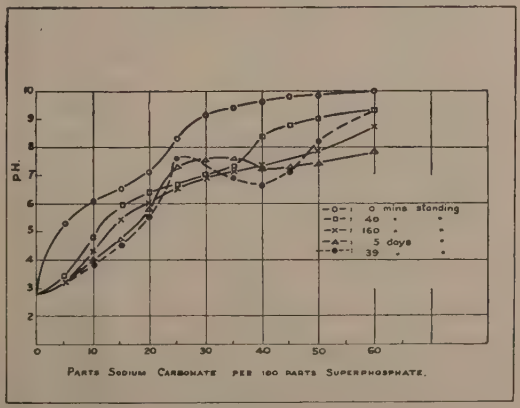

Figure 3.

would appear that the use of Group I compounds (carbonates of calcium or/ and magnesium) offers several advantages:—The quantity is not extremely critical, and the possibility of prosphate fixations would seem to be less than in the case of the more alkaline hydroxide or oxide. Group 3 compounds, due to their cost could not be economically used.

Conclusions

(1) There is a marked change in the pH of aqueous suspensions (1:5 mix-water ratio) of "Basic Superphosphate" with time, suggesting perhaps that, in the testing of these mixes, a pH-time curve should be aimed at instead of an individual figure determined after an arbitrary time of standing.

(2) There is a possibility of phosphate "fixation" taking place in these mixes or when applied to the soil, especially in the case of hydrated or quick lime.

(3) The quantity of Group I compounds (carbonates of calcium and/or magnesium) used in the preparation of the "basic superphosphates" is not as critical as in the case of Group 2 compounds (hydrated or quick lime) and therefore the former should be more suitable for "on the spot" mixing on the farm.

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CUTICULAR SCALES OF WOOL: THICKNESS AND VISIBLE LENGTH

The wool fibre cuticle is essentially a thin sleeve of imbricated cells, whose serrated edges project in the direction of the distal fibre. Hirst and King (1926) and Wildman (1954) have suggested that the cuticle cells overlap. The former consider that the thickness is a function of the length of the cell and the sine of the angle which the cell makes with the surface of the cortex. Frolich, Spottel and Tanzer (1929), summarising the estimates of several workers concluded that the individual cell is 0.5 micron thick and quoted a maximum scale thickness of 3 microns. Appleyard and Greville (1950), examining the scales of Lincoln and Leicester fibres under phase contrast, with ultra violet light of 3650 Angstroms under the optical microscope, have recorded scale thicknesses as 0.66 micron and the length as approximately 30 microns, with an overlap of one-sixth of the length. Rudall (1941) has suggested that cuticle scales are of a uniform size and where thicker cuticles than 0.5 micron are experienced, these are due to the repetition of the unit cell.

During recent measurements of the cuticle of Australian wool grades from 32's to 80's and the Pakistani carpet wool grades, known as super, medium and coarse, some evidence at variance with the above was disclosed.

To differentiate cuticle clearly from the cortex which it envelopes, at an optical microscope magnification of 1,000 dia-

meters cross sections were stained with picroformol; 0.5 gram of picric acid was dissolved in 100 mls of dilute formaldehyde at room temperature. After 15 minutes immersion the sample was washed until the colour contrast was that desired. This contrast could be enhanced by dipping the fibres in 1 per cent. acetic acid for five minutes. Cuticular thicknesses were measured on 100 fibres from each quality, number and grade.

Visible scale length was measured on plastic casts of one side of the fibre, so that the form of scales on the opposite side of the fibre would not interfere with measurement. Polyvinyl acetate (M.P. 80 deg. C.) in the form of a 20 per cent. solution in benzene was used.

The results of measurements are given in Table I.

The correlation coefficient for visible scale length with fibre thickness is low (0.13). Visible scale length varied very little, over such a wide range of wools.

If scales be considered as imbricated laminae, there will be a maximum thickness where the laminae overlap and minima between. If the scales overlap on an average of one-sixth of their length, then if their angle with the axial direction of the fibre is A, $\sin^{-1}A$ approximates to 0.07. Therefore maxima can be expected to be slightly less than twice the actual scale thickness, if there are two scales in contact, and the minima slightly less than a single scale thickness. If cuticular scales are uniform in size, then in fibres with increased scale thickness, the greater thickness would be a multiple of the unit cell. Such reasoning may be expecting too great a uniformity from a biological material. However close examination of the minimum cuticular scale thickness in Table I shows that the minimal values may all be reduced to a multiple of 0.415 microns, approximately. The same holds for the maximal values. This suggests that the unit cell may be of 0.415 microns thickness. It might have been expected that maxima would be twice the value of their respective minima and while this pertains in six cases, there are also seven exceptions. This would suggest that the

TABLE I.

Cuticular scale thicknesses mean, minimum and maximum and visible scale length for Australian 32's to 80's and Pakistani carpet types.

Quality No.	Cuticular Scale Thickness (microns)			Mean Visible Scale Length (microns)	Mean Fibre Thickness (microns)
	Minimum	Maximum	Mean		
80's	0.83	1.66	1.05	11.3	17.3
70's	0.83	1.66	1.02	10.8	18.5
64's	0.83	2.07	0.94	12.1	22.2
60's	0.83	2.07	1.08	10.7	23.8
56's	0.83	2.07	1.14	12.9	27.3
50's	1.25	2.49	1.52	15.3	30.3
48's	0.83	2.07	1.37	17.7	32.8
44's	1.25	2.91	1.90	16.7	35.8
40's	1.66	3.32	2.38	16.6	40.3
36's	1.66	2.49	2.20	16.8	40.1
Pakistani					
Super	1.66	3.73	2.58	18.2	35.3
Medium	1.66	3.32	2.53	15.5	42.6
Coarse	1.66	3.32	2.52	17.6	55.1

cuticle may not be uniformly of the same number of unit cells throughout, but may at least vary by one at different levels in the fibre. The minimal thickness would indicate the smaller grouping and the maximum, the greater. There was similarity between the Australian and Pakistani wools in the results tabulated.

In conclusion, Table I has suggested a slightly thinner cuticle cell unit than has been reported, as well as the possibility that even in the finer wools the cell unit may be duplicated. It also appears that there may be variations in the number of unit cells in the cuticular thickness in some fibres.

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BOOK REVIEWS

FERTILITY FROM TOWN WASTES

By J. C. WYLIE

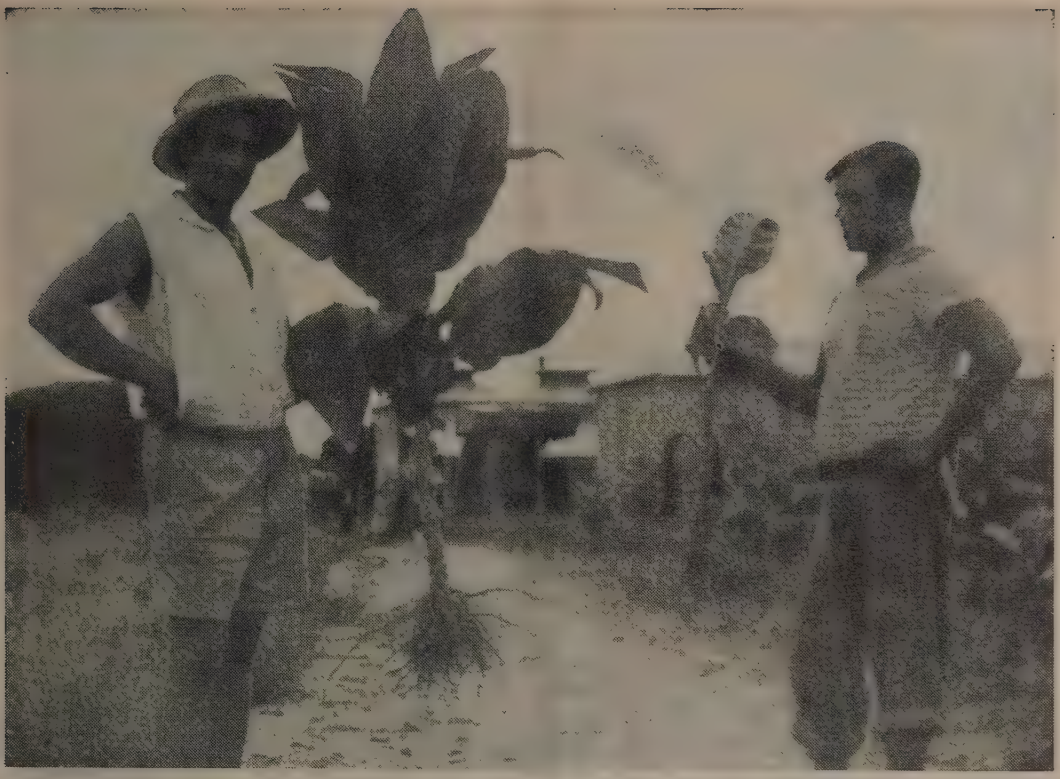
(*Faber and Faber*, 1955, 41/6)

The disposal of the town wastes—garbage and sewage—is discussed in detail by the author, who has pioneered the establishment of a series of successful garbage/sewage composting plants in the County of Dumfries, Scotland. Past and present methods of town waste disposal are described, and their disadvantages elaborated. Composting of waste materials is recommended as a method of disposal to overcome fouling of rivers, dumps of stinking rubbish and, most importantly, to conserve valuable organic wastes for the maintenance of soil fertility. The book is dedicated to Lady Howard and much space is devoted to the value of organic matter in relation to food supply. The mechanised process of garbage (sewage) disposal, developed by the author at Kirkconnel, is described section by section, and is well illustrated.

The chapters on economic and commercial aspects are confused by the proposition that local authorities are under an obligation to dispose of their wastes in the most satisfactory way, which precludes the burning, or burying of organic waste materials.

This book is commended to all who have some responsibility, or interest in either the disposal of town wastes or intensive farming. However, it is suggested that the adoption in Australia of the methods of waste disposal advocated by this book, will need to await more detailed and factual information on the economics of production and commercial aspects of the sale of the compost.

R. O. KEFFORD.



Tobacco plant grown in fumigated soil compared with plant from untreated ground.

Meet the Eelworm

Like most microscopic soil pests, the eelworm is a born saboteur

Working underground, unobserved and undisturbed, he eats into the life-roots of young tobacco plants.

Australian tobacco growers are fighting a constant battle against eelworm attack. Thanks to Shell scientific research, a powerful soil fumigant* derived from petroleum is helping tobacco growers to control eelworm.

Production Doubled

The total acreage and dried leaf production of Australian tobacco has more than doubled over the past five years. The tobacco industry is now taking its rightful place among the great agricultural industries of the Commonwealth. Shell research is doing its utmost to assist the tobacco grower in seeing that increased production is maintained.

Once again we find Shell scientists serving an important Australian industry by developing and marketing a major agricultural aid.

*Shell Soil Fumigant E.D.B. (15).

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NEWS ITEMS

Water Research Foundation of Australia

A number of grants to the Foundation have been made by industry, the total sum at 9th May being £3,600. This sum has been donated by the following firms: James Hardie & Co. Ltd., Ames Irrigation Pty. Ltd., Stewarts and Lloyds (Aust.) Pty. Ltd., Australian Aluminium Co. Pty. Ltd., Dangar Gedye & Malloch Ltd., and The Land Newspaper Ltd.

The Chairman of the Foundation, Mr. J. G. Beale, M.L.A., said in Sydney that the response so far from industry had been very encouraging. The grants will help to initiate and promote scientific and technological research, soon to be undertaken or sponsored by the Foundation, into the immense and urgent problem of the development, control and use of the water resources of Australia.

The Foundation was established with these objectives in November 1955; its headquarters are in Sydney.

International Rust Conference

Associate Professor I. A. Watson has returned to the University of Sydney from sabbatical leave spent in North America during which he worked at the University of Minnesota on problems of rust resistance in wheat. Dr. Watson was also Commonwealth representative at the International Rust Conference held at Mexico City last March.

The Conference was attended by more than 100 delegates, mainly from Central and South America. There was much discussion of new techniques in plant breeding, particularly irradiation as a means of accelerating genetic changes. Dr. Watson considers that the irradiation techniques being developed look very promising and are capable of wide application.

Mexico City was chosen as the venue of the Conference because the Rockefeller Foundation is engaged on an ambitious project designed to improve the notoriously low food standards of the Mexican people. The improvement programmes for wheat, corn, potatoes and other crops covering agronomic techniques, introductions and accelerated breeding work, all of which are being carried out in Mexico, Dr. Watson found to be tremendously impressive both in quantity and quality. It is interesting that, at present, Gabo is the leading wheat variety in Mexico although it is rapidly being replaced by varieties more closely suited to local conditions.

Seeds Officer for Conference in Paris

Miss Amy Myers, seeds officer in the N.S.W. Department of Agriculture left Sydney early in May to represent Australia at the triennial Conference of the International Seed Testing Association at Paris in June.

Miss Myers will also visit seed testing laboratories in Great Britain and Europe.

The International Seed Testing Association is the recognised world authority for the administration of seed testing and has a membership of 56 countries.

Miss Myers has been the senior seed testing officer of the N.S.W. Department of Agriculture for many years. She is the author of "A Manual of Seed Testing," the only Australian textbook on the subject and has also published a number of scientific papers.

Novel Tillage Implement

A farmer from the South Coast of New South Wales, Mr. Tom Solness, of Bomaderry has invented a tillage implement called a multi-cultivator that offers a new approach to cultivation.

The cultivator is tractor-drawn and driven from the power-take-off. It lifts above the ground two 30 in. wide slices of earth taken from adjusted depth of from 3 to 10 in. and, at the same time, the loosened soil is sliced into sods approximately 4 in. by 4 in. and then dropped back into the same furrow.

Each of the two linked assemblies drawn by the tractor consists of a 30 in. wide, adjustable shear blade above which is a knife "drum" carrying a large number of angled cutter knives.

Noteworthy features of the operation of this machine are that no sub-soil is brought to the surface, it does not pulverize the soil and it definitely breaks up and aerates the soil at any of the adjusted depths.

Mr. Solness's cultivator has been tested by farm mechanization officers of the N.S.W. Department of Agriculture with very satisfactory results. At a cultivator depth of 9 in. and a tractor speed of 2¾ m.p.h. the multi-cultivator can cover, in any soil, 12-14 acres per 8-hour day.

Aerial Top-Dressing Record in New Zealand

A world record in the aerial top-dressing of pasture is believed to have been established on a farm at Hawke's Bay, New Zealand. In one day a single aircraft spread 230 tons of lime, reports the N.Z. Government information service.

The pilot started work at 5 a.m. and continued until dusk, flying one of the new Fletcher aircraft with a capacity of 15 cwt. It is estimated that the pilot landed and took off more than 300 times during the day.

This method of scattering top-dressing is now employed freely by New Zealand wool-growers to bring fertility to large areas of pasture, especially in hilly country.

Black Spot Control in N.S.W.

Black Spot is a serious disease of apples and pears which, in 10-12 cover sprays during a season, is costing the industry about £500,000 per year.

The Chief Biologist of the N.S.W. Department of Agriculture, Dr. C. J. Magee has given details of a new cheap spray technique which is expected to give complete control of the disease.

It is one thorough post-harvest, autumn, eradicant spray with phenyl mercuric chloride followed by a similar spraying twelve months later. The object is to cover all leaves and twigs, both on the tree and on the ground, with the fungicide and so prevent spore germination in the spring.

Several years work by Mr. K. G. Hutton, the pathologist in charge of the investigations in N.S.W. have shown the treatment to be fully effective. In co-operation with the Division of Horticulture it is now being demonstrated on district basis at Yetholme, near Bathurst. For an eradication campaign of this sort full grower co-operation is essential and it is in this that the only serious difficulties are likely to be experienced.

Potash Fertilisers used in Australia

During the past twelve months there has been a further increase in the consumption of potash fertilisers used on major agricultural crops in Australia.

The most spectacular increases have occurred in fruitgrowing, potatoes, tobacco and pastures. The quantity of potash used on pastures during 1955 was more than double the 1954 usage, and almost seven times that of 1953. The actual figures are as follows:

1953	438 tons
1954	1,315 tons
1955	2,978 tons

The total quantity of potash used on all crops in Australia during 1955 was 26,863 tons compared with 23,659 tons in 1954.

Forms of Potash used

The quantity of sulphate used has increased during the past year and it now represents 12.3% of total usage.

Muriate of potash still accounts for the bulk of potash fertiliser at present used. Free running muriate is becoming more popular and represents about 15% of present muriate sales.

Scholarships Available for Study Overseas

In the September-December, 1949 issue of the Journal of the Australian Institute of Agricultural Science was published the report of a Council Sub-Committee listing the scholarships available in the Commonwealth of Australia for agricultural workers to gain experience abroad. In 1955 Council decided this list should be brought up to date, and republished. It was found however, that other comprehensive publications are now readily available.

Agricultural scientists who wish to study abroad are advised to seek information in "Study Abroad," a UNESCO publication issued at approximately yearly intervals. The latest issue is 1955-56, and it includes references to scholarships available in Australia, and also to scholarships available in the United Kingdom to students in other countries of the British Commonwealth.

Saving Water in Arid Regions

Americans are taking up C.S.I.R.O. research using cetyl alcohol to reduce evaporation from water storages.

Mr. W. W. Mansfield, who has been responsible for the Australian research, recently visited Texas where he outlined to a conference convened to discuss his work, the results of large scale tests in Australia.

Recent tests in four Australian States, carried out with the co-operation of several water authorities (State, municipal and private), on dams and reservoirs with areas ranging from 2 to 20 acres have confirmed earlier small-scale tests in showing that evaporation may be reduced by between 20 and 70 per cent. depending on conditions.

In arid regions where water supplies are inadequate and often unreliable, evaporation losses of up to 8 feet of water occur annually. This loss may be greater than the amount of water which remains for use.

Mr. Mansfield's process maintains a thin invisible film of cetyl alcohol on the surface of the water. This restricts the transfer of water to the air but does not prevent oxygen being dissolved from the air to keep water fresh. Where normal evaporation is 8 feet per year, a saving of 45 per cent. means a saving of 1,000,000 gallons of water for every acre of reservoir surface.

The cost of treatment calculated from the recent experiments amounted to about 2½ pence per 1,000 gallons of water saved.

The method is still in the experimental stage and much work remains to be done before it will be sufficiently "foolproof" to be applied generally.

Overseas interest in the work has already resulted in supplementary tests being arranged in several countries, including India and Kenya. They have, in common with Australia, large areas which are desperately short of water.

"Brian Pastures" Pasture Research Station

"Brian Pastures" pasture research station, Gayndah, which was established following an agreement between the Australian Meat Board, the Queensland Government and the C.S.I.R.O., was opened officially on 1st May, 1956.

The opening ceremony was in the hands of *Messrs. J. L. Shute*—Chairman and Commonwealth representative on the Australian Meat Board (A.M.B.), *F. A. Brodie*—member of Executive Committee of A.M.B. and Chairman, Australian Beef Cattle Research Committee, *A. F. Bell*—Under Secretary, Department of Agriculture and Stock, *Drs. J. Griffiths Davies*—Associate Chief, Division of Plant Industry, C.S.I.R.O., and *W. A. T. Summerville*—Director, Division of Plant Industry, Department of Agriculture and Stock, and Chairman, "Brian Pastures" Technical Committee.

The inspection of the research investigations in progress at "Brian Pastures" was conducted by specialist officers including *Messrs. N. F. Fox, M. A. Burns, T. G. Graham, N. D. Young, P. C. Davidson* and *N. H. Shaw.*

The object of the Station may be stated as the exploration of the practicabilities of increasing beef production by improving pastures, developing more efficient methods of pasture use and maintenance, providing supplementary feed and by animal health and husbandry investigations.

The A.M.B. has been responsible for capital expenditure to the extent of approximately £100,000 on "Brian Pastures." The Australian Beef Cattle Research Committee controls the general policy. The research programme is supervised by a Technical Committee composed of representatives of the Department of Agriculture and Stock, C.S.I.R.O., and the United Graziers' Association. The Queensland Department is responsible for staffing, maintenance and running costs, the control of stock on the property and for carrying out of most of the research programme. C.S.I.R.O. is responsible for pasture nutritional studies on a granitic soil type on the property.

The foundations of the research programme planned for the property have been laid down and in fact some of the experimental areas have been under observations for twelve months or more.

Poultry Flock Improvement Scheme

The urgent need for poultry flock improvement has been recognised both in the State of Queensland and on a national level. This year almost £9,000 has been made available to the Queensland poultry industry from the Commonwealth Extension Services Grant. The finance will be largely used to provide permanent facilities for random sample testing, because such testing is an integral part of any improvement plan. Money will be avaiable to assist breeders who are willing to undertake flock improvement, for it is realised that the establishment of a breeding programme on a farm calls for extra labour and expense.

Production per bird cannot be improved simply by selecting birds on showring standards. A permanent and substantially increased production can only be obtained by employing a long-term breeding programme based on progeny records. Where a genetically sound breeding plan is in operation it is expected that for some years the egg production in a flock will rise by four to five eggs per bird per year.

A recent survey of egg production in Australia by the Bureau of Agricultural Economics shows that Queensland has the highest production per bird in the Commonwealth. Although the Queensland figure is 158 eggs per bird, the need for improvement is apparent when this is compared with production in other leading poultry-raising countries. In Holland, for example, the average annual production is 22 eggs per bird higher than in Queensland.

Visiting Scientists

A recent visitor to Brisbane and Toowoomba was *Dr. Lyle T. Alexander,* Chief of the Soil Survey Laboratory of the Soil Conservation Service of the U.S. Department of Agriculture. During a very short stay in Australia, he also visited Sydney, Adelaide and Melbourne in order to see as much as possible of laterite formations and types of red soils known as Latosols in the U.S. Soil Survey.

In Queensland, in company with *Professor L. J. H. Teakle and Messrs. G. D. Hubble, A. Martin* and *C. R. von Steiglitz,* Dr. Alexander inspected laterites and red soils in the Toowoomba area. He observed similarities between these laterites and those of Central Africa, especially in the Congo region. Particularly valuable contributions to the understanding of the soils of the Toowoomba area were his recognition of transported material in some laterite exposures and of volcanic ash occurring as a thin surface layer on a high level red soil.

Dr. J. G. Horsfall, Director of the Connecticut Agricultural Experiment Station who recently paid a flying visit to Queensland before returning to the United States, via Europe. Dr. Horsfall, who is an authority on fungicides (one of his better known publications being "Fungicides and their Action") came to this country after an assignment with the New Zealand Fruitgrowers' Association.

Dr. Harlan K. Pratt, Assistant Professor of Vegetable Crops in the University of California at Davis, who is travelling as a Fulbright Scholar is spending some months of his sabbatical leave as a guest worker with the Division of Food Preservation and Transport of the C.S.I.R.O. Dr. Pratt's special interest is the post-harvest physiology of vegetable crops.

Professor L. King of the University of Natal recently visited the South Eastern Regional laboratory of the Soils Division, C.S.I.R.O. Prof. King, who is a geomorphologist, had discussions concerning aspects of time phases in the Australian landscape.

News from Western Australia

Citrus Growers' Conference

The Australian Citrus Growers' Federation held their annual conference in Perth from May 2nd-4th. The first two days were devoted to discussions, and lectures were given by Messrs. Melville, Jenkins and Cass-Smith, of the W.A. Department of Agriculture. A delegate showed interesting colour slides recently taken by him when on a world tour, and in which many aspects of citrus growing were illustrated. On the last day an excursion of citrus growing regions was held and this was followed by a dinner at which senior officers of the Horticultural Division, Messrs. Powell, Eckersley and Melville, were present.

Vegetable Research Station

The new Vegetable Research Station near Perth is now well into its initial development stages with the laying of roads and portion of the irrigation system. The soils are similar to those of many commercial growing districts and the station is expected to be available for initial trials in the near future.

New Building

The foundation stone of the new £300,000 Department of Agriculture building was laid recently. This will supply central accommodation for much of the Departmental staff and the provision of modern laboratories will be of great value to specialist officers.

Beef Cattle Conference

Mr. M. Cullity, Liaison Officer for W.A. on the Technical sub-committee on Beef Cattle Production, recently acted as chairman for the committee at its annual conference, which was

held in Perth. The recent meeting enabled a review to be made of the work in each of the states, and for recommendations to be formulated regarding work in coming years.

The present work of the committee is the study of beef growth rates in Southern Australia, a study which was initially begun in N.S.W. in 1949. Growth under usual management conditions is studied for a period of 5 years, in order that climatic variations and differences are ironed out. However 3 years is considered sufficient in the agricultural areas of this State. Another most important subject discussed was dwarfism, a hereditary defect of beef cattle which in recent years has become widespread in the United States of America. Mr. N. Davenport, of the W.A. Department of Agriculture also attended the conference as an official delegate.

International Conference of Agricultural Economists

The International Conference of Agricultural Economists is an international association which was founded in 1929 by a group of British and American agricultural economists. Its object is to foster the development of agricultural economics in different countries, and to further "the application of the results of economic investigation of agricultural processes and agricultural organisation in the improvement of economic and social conditions relating to agriculture and rural life."

Membership is open to any person interested in promoting the objects of the Conference. No professional qualifications are required and no formal procedure of admission is followed. The present membership exceeds 500, distributed among some 50 countries. The majority of members are professional agricultural economists engaged in research, teaching or public administration, but the membership is also representative of a wide range of agricultural and economic interests.

Conferences are organised at three-year intervals, and are on an international basis. The proceedings of these conferences contain a survey of contemporary economic problems in Agriculture discussed by leading Agricultural Economists.

The International Conference of Agricultural Economists is currently seeking increased Australian participation in its activities. Membership is invited from interested persons or organisations in this country. The Subscription for the ensuing three-year period until the 1958 Conference is £A2/10/-. Members receive a copy of the Proceedings of the 1955 Helsinki Conference, current issues of the *Journal of Agrarian Affairs*, and other periodical publications. Intending members should forward their subscriptions to Dr. K. O. Campbell, I.C.A.E. Correspondent for Australia, School of Agriculture, University of Sydney, Sydney, from whom further details of the association may also be obtained.

Codling Moth in Western Australia

The discovery of Codling Moth at Bridgetown at the end of February this year is causing much concern. This district is the largest fruit growing district in the State and under normal conditions produces approximately 600,000 bushels of apples.

One commercial orchard is heavily infested and slight outbreaks have been found on a number of other orchards scattered throughout the district.

An eradication campaign is being planned by the Superintendent of Horticulture, H. R. Powell, and the Government Entomologist, C. F. H. Jenkins, and it is hoped that when implemented, the outbreaks will be eradicated.

Gummosis Control Campaign in S.A.

A vigorous campaign for the control of apricot gummosis was launched by the S.A. Department of Agriculture in May. Recent findings by Waite Institute plant pathologist, Mr. M. V. Carter showed that the disease is spread from old wood by wind borne ascospores. Intense publicity by means of circulars, theatre advertisements, radio and press articles aims at a clean up of dead wood by the fruit growers themselves. The Department also recommends the adoption of their recently developed modified pruning techniques.

World Wool Use Increased in 1955

World consumption of virgin wool rose during 1955 with impressive increases in U.S.A., West Germany, Japan and Canada, according to a recent report by the Australian Wool Bureau.

The Bureau quoted estimates compiled by the Commonwealth Economic Committee of a 1955 world wool consumption of 2,580 million lb. (clean). This is an increase of 3 per cent. on 1954 (2,502 m. lb.) and is the third largest wool use since the war. It is exceeded only by 1950 (2,681 m. lb.) and 1953 (2,631 m. lb.) clean weights.

In 11 countries which together use about two-thirds of the world's wool, consumption last year rose 4 per cent. more than 1954, with outstanding increases in the U.S.A. (9 per cent.), West Germany (9 per cent.), Japan (13 per cent.) and Canada (22 per cent.). United Kingdom, still the major wool user of the world, increased its wool use by 3 per cent., and there was a sharp increase of 14 per cent. during the last quarter of 1955.

Outside the 11 large manufacturing countries, wool consumption in the rest of the world last year is estimated by the Commonwealth Economic Committee at 2 per cent. more than in 1954.

The consumption in wool textile production of materials other than virgin wool rose last year by 8 per cent., to the highest total since the war, in 10 major consuming countries. These alternative materials include wool by-products and recovered wool as well as non-wool fibres.

Adelaide Fruit Fly

Towards the end of the peak danger period, fruit fly was reported for the first time in 1956 in the Adelaide metropolitan area in April.

Russians Visit Waite Institute

In April a party of eight Russian scientists from the icebreaker Ob visited the Waite Institue in Adelaide. They were members of the Soviet Antarctic expedition. Although marine biologists and chemists, they showed particular interest in details of Australian survey work on laterites and red-loams, for ferric oxide forms an important part of Antarctic ocean sediments.

Survey of Beef-Cattle Industry

The printed report of a survey of the beef-cattle industry of Australia carried out in 1946-52, by Mr. W. A. Beattie to provide a background for the future planning of research has been released by C.S.I.R.O. as its Bulletin No. 278.

Much of the information in the report has been released in earlier progress reports but the printed document brings all the data together in one cover.

The survey aimed to determine and define the structure of the industry as it has evolved in a variety of climatic environments within Australia. Attention has been given to the conditions in each of the natural regions, action that may be taken to enable cattle to survive or thrive in them, the breeds of cattle available, methods of animal husbandry, disease and pest control, stock routes and transport, land tenure, labour, and the social structure. These factors all have an important bearing on the success of the industry.

The report is divided into four parts, the first of which traces the history of the industry in Australia and outlines the distribution of beef cattle throughout the continent.

Parts 2 and 3 deal with the industry in Northern and Southern Australia respectively, while Part 4 sets out the general position of the industry as it is today.

New S.A. Wheat Named

Another wheat variety bearing a weapon name has been registered by Roseworthy Agricultural College, S.A. Known as RAC 20 until March, Claymore results from the cross Gabo x Dundee x Caliph. Dr. R. N. McCulloch, Roseworthy principal, says the new wheat could well be used to replace Bencubbin in S.A. as a mid-season variety. Gabo-type rust resistance is backed by reasonable flag smut resistance and medium-strong flour quality.

Careers Exhibit, Chemex, Melbourne

The Victorian Branch of the Australian Institute of Agricultural Science conducted an exhibit on careers in agricultural science at Chemex, the exhibition on chemical industry organised by the Royal Australian Chemical Institute on 10th-26th May, 1956.

The Royal Australian Chemical Institute offered the Australian Institute of Agricultural Science space, free of charge, for the purpose of illustrating the role of the agricultural scientist, and the place of chemistry in agriculture. The exhibit was designed around the central theme of the Soil Chemist, and the compilation of soil maps by the use of aerial photographs, field exploration and chemical analysis.

One-third of the exhibit illustrated the other major avenues for careers in agricultural science. A small leaflet was prepared, and widely circulated to attract attention to the opportunities for careers in agricultural science, and the Institute's brochure.

Attendances at the exhibition were well over 50,000 (actual figures are not yet available). As the exhibition was conducted during the school holidays, large numbers of school children attended.

The exhibit was organised within 10 days, due to the excellent co-operation between the Department of Primary Industry, the Victorian Departments of Agriculture & Lands, the State Rivers & Water Supply Commission, and Soil Conservation Authority, and Institute members in private industry.

It is hoped the basic material of the exhibit will be used again in the N.S.W. Branch Exhibit at the Careers Exhibition in Sydney, 27-31st August 1956.

BOOK REVIEWS

THE PIONEERING PIG

By NORMAN BLAKE

London, Faber and Faber, 1956—12/6

This is not the usual kind of book on pigs. It is not meant to teach the reader everything that is known about pig raising. It deals specially with the use of pigs as improvers of virgin or developed land. The author believes that improved soil fertility can be just as much a product of the pig as is pork.

Pigmanship is shown to be more important than elaborate equipment of a piggery.

Although written on English conditions, the principles dealt with in this book are applicable in Australia.

Anyone with an interest in pigs will enjoy reading the facts, wisdom and wit, apparently acquired by the author from many years of experience in pig raising, and packed in this book of less than 100 pages.

L. A. DOWNEY.

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TALKS

"The Inter-relation of Legumes, Rhizobium and Nutrients"

Dr. D. O. Norris, Principal Research Officer, Plant and Soil Laboratory, C.S.I.R.O., Brisbane.

This entire session at the Plant Nutrition Conference was strongly dominated by the subjects of subterranean clover and superphosphate. Of the twelve papers presented, eleven dealt in one way or another with clover, particularly subclover. The twelfth paper struck a new line, dealing with tropical legumes.

Outstanding impressions that emerged from the papers and the discussion were—

(i) The very heavy emphasis of Australian research on clovers and medics;

(ii) The completely empirical approach of the workers attempting the establishment of clovers on problem soils in various parts of Australia. These workers do not appear to be interested in soil analyses and have no idea of the base exchange complex of the soils on which they work. Without such data one cannot even guess at what might be going on with additions of lime and super-phosphate to the soils. With such data one might still have to guess, but the guess has a better chance of being intelligent.

"Dry Farming Patterns in Queensland"

Dr. L. G. Miles, Assistant Director of Agriculture, Department of Agriculture and Stock, Queensland.

It has been amply demonstrated within the 20" to 30" rainfall belt of south and central Queensland that the reliability of crop production can be greatly increased by moisture conservation in suitable clay soils. In most years, the State's winter-spring crops are dependent more upon stored moisture than upon rain falling during growth. Even with summer crops, which are grown during the period of highest rainfall expectancy, the value of a "season in the ground" has been repeatedly demonstrated. Since satisfactory moisture trapping normally requires a period of some months of weed-free fallow, the principle can only be safely applied to relatively flat land or land which has been adequately protected from loss by erosion. Wherever possible, stubble conservation should be adopted during fallow periods, and further research is required into methods of handling heavy stubbles during such periods.

While moisture conservation demands the exposure of soil during periods of considerable rainfall, the principles of soil conservation demand equally that the soil should be protected during such periods. Even on flat country, where actual soil movement may be regarded as negligible, the fallowing system is exploitive and must result in deterioration of soil structure, thus eventually defeating its own ends.

Such deterioration may be very slow on the heavier plains soils of the central and north-western Darling Downs, but it is clearly quite rapid in some of the "brigalow" and other soil groups. For the great majority of these soils therefore, if not for all, a pasture phase will be an absolute necessity if the present dry-farming pattern is to fit into a stable and lasting Queensland agriculture.

"Control of Water in the Soil"

Dr. T. J. Marshall, President S.A. branch A.I.A.S.

Dr. Marshall commenced his address by pointing out that over a great portion of the earth water is limiting to plant growth either because of excess or deficiency. It was therefore necessary to consider the ways by which water could be controlled in the soil. He considered the control of soil water under three main headings:—

(a) the soil as a store for water,

(b) control of gains and losses of water to the store,

(c) measurement of water in the store.

In discussing the first heading, Dr. Marshall drew attention to the available range of soil water which extends from a water content corresponding to a suction of 100 centimetres of water to 16,000 centimetres. For practical applications the difference between these water contents is expressed on a volume basis—as a depth of water per given thickness of each soil horizon. The maximum amount of available water retained by the soil depends on the texture and structure of the soil and rooting depth of the crop.

A recent controversy concerning the availability of soil water was discussed by Dr. Marshall. Veihmeyer in California contended that water is equally available to plants anywhere within the available range. This idea has had a large influence on irrigation practice. Other workers have argued that the water within this range is not equally available to plants. Dr. Marshall said there were, from a physical point of view, strong reasons for believing that water was not equally available. He said that as the soil dried plants had to withdraw water which was held at a higher tension and further as the soil dried the mobility of the water was greatly reduced. The effect of mobility on the water uptake by plants was not considered important, but recent work in the Soil Physics section has shown that water can move in the liquid phase down to the wilting point.

Dr. Marshall explained how the chloride ion was used in these experiments to separate flow of water in the liquid and vapour phases.

Under heading (b), Dr. Marshall discussed irrigation and infiltration of rain. He mentioned that in irrigation practice two questions were asked: "how much" and "when" and because of this there was a keen demand for methods for

measuring the changing water content or tension of water in the soil. In discussing infiltration, he drew attention to the large effect that surface seals formed by rainfall impact on unstable soils, could have on water entry; this could result in seals of 0.1 mm. thick, the permeability of which is over two thousandth of the soil immediately below.

Two aspects of water loss from the soil were considered, evaporation and drainage. Dr. Marshall indicated some possibilities for research on reduction of water loss directly from soils by evaporation. He discussed the effect of thermal gradients on the movement of soil water.

Dr. Marshall said that drainage designs have been worked out mainly on the basis of soil profiles and experience. At present methods being developed by Childs and Kirkham show promise for *in situ* measurements of permeability in saturated soils. In time these may well provide a sound basis for drainage design. To follow the loss of water from a soil and to find out when it is necessary to irrigate, some measure of water content or tension of the soil in the field is often wanted.

Dr. Marshall discussed the various experimental procedures which can be used for these purposes. He mentioned the limitations of the various methods. One method which has only recently come into use was explained. Fast neutrons emanating from a radium—beryllium source are slowed down and scattered by hydrogen atoms, the slow neutrons diffusing back to a boron trifluoride counting tube are counted. For a given soil, changes in water content give rise to changes in the hydrogen content of the soil and this latter change is readily measured. A neutron moisture meter for field use has been built up in the soil physics section.

In conclusion Dr. Marshall considered the components of a balance sheet of water loss (due to evaporation, transpiration, run-off and drainage) and gains (by precipitation and irrigation).

"The Diagnosis of Nutritional Deficiencies and Excesses"

I. F. Fergus, Chemist, Department of Agriculture and Stock, Queensland

At the Plant Nutrition Conference this subject was discussed under five headings:

(1) *Chemical Analysis of Plants*: Special reference was made to the establishment of critical ranges, and several papers presented evidence for the critical levels of some nutrients in different plants. Difficulties which were mentioned were sampling error, part of plant to be sampled, antagonistic ion effect, and variability of nutrient level due to the age of the plant.

(2) *Chemical Analysis of Soils*: Papers presented dealt in the main with phosphorus, potassium, sulphur and manganese. One author discussed the ratios of sulphur to carbon and nitrogen for a number of soils, but was unable to obtain a correlation with plant yield or uptake of sulphur. Discussions on lime induced chlorosis showed there has been only partial success obtained by the addition of iron chelates to the soil.

(3) *The Use of Indicator Plants*: Agreement was reached that this can be a useful field method of diagnosis. Difficulties mentioned by one contributor were—each nutrient deficiency does not produce separate and distinct symptoms, symptoms can vary from plant to plant, in some cases different disorders give similar symptoms, and fourthly other environmental factors can cause symptoms resembling those of a deficiency.

(4) *Using bio-assay techniques*: The microbiological assay of available phosphates was investigated, using two fungi in particular. Assays of the availabilities of a number of phosphatic substances to this fungi were carried out.

(5) *Using pot-culture techniques*: The merits of pot trials were discussed, and the point made that results of pot trials are not always identical with field responses. These differences could be due to ideal water conditions in pot work, or higher temperatures under glasshouse conditions possibly affecting availability of nutrients, or an increase in nitrification which can occur under pot conditions.

"Viticultural Research"

B. G. Coombe, Horticultural branch, S.A. Department of Agriculture.

Mr. Coombe said that grape growing was carried on with a small profit margin and that the industry, particularly in low rainfall areas, could not stand much increase in the cost of production.

The industry has been remarkably free from pests and diseases but vine scale, mites, nematodes and others appear to be increasing. The use of T.M.T.D. has effectively controlled black spot but mould at harvest still causes concern. Collar rot of "dying vine" disease eludes clarification, and is responsible for the death of many vines in South Australia.

A suspected bacterial disease and suspected virus diseases are causing concern and work is expanding on this aspect.

Departmental work was intensified on currant setting because of the high labour costs and the premature decline of the vine associated with cincturing. The acreage of currants in South Australia had fallen from just below 11,000 in 1941 to approximately 8,000 acres in 1952.

Following work on the setting of tomatoes with growth regulators, work was commenced in 1947 testing their effect on uncinctured currants. In 1949 the substance para chloro phenoxy acetic acid (P.C.P.A.) at 50 p.p.m. gave promise and future work concentrated on this chemical.

From concentration trials it was found that the toxicity level was low there being no damage to bunches at 75 p.p.m. and only very slight damage at 250 p.p.m. Mould in bunches increased at higher concentrations and this was the limiting factor in choosing a concentration of 20 p.p.m.

Mixing with fungicides inactivated the growth substance.

It was found the optimum time to apply P.C.P.A. was as soon as all flower caps had fallen.

No lowered fruitfulness has been observed in vines sprayed for 5 years, but where a high

concentration was used with repeated sprayings at intervals of a few hours, fruitfulness the following year was severely reduced.

An increase in the incidence in black spot has been noted in sprayed vines in comparison with neighbouring cinctured vines. It is also suspected that Oidium incidence is increased but as yet there is no direct evidence to support this.

Growers have enthusiastically adopted the spraying treatment with P.C.P.A. for setting in place of cincturing with notable responses in vine vigour.

The effects of 2,4-D and B.T.O. have been compared with P.C.P.A. and cincturing.

Present work is centering on the use of mixtures of P.C.P.A., 2,4-D and B.T.O.

"Agricultural Production and Possibilities in New Guinea"

Dr. H. C. Forster, Executive Officer, C.S.I.R.O.

The Territory of New Guinea includes some 183,000 square miles with a wide diversity of environment—ranging from the uplands with an elevation from 4,000 to 15,000 feet and a rainfall of 100 to 200 inches to the coastal swamps with a tropical environment. The only area of comparative low rainfall is in the region of Port Moresby with a rainfall averaging 40 inches and open savannah vegetation rather characteristic of northern Australia. This range of conditions enables residents to produce a very wide range of agricultural crops including normal temperate crops such as wheat, barley, coffee and stone fruits in the highlands and coconuts, cocoa, rice and rubber in the tropical lowlands. Secondary industry, in the form of timber and plywood production, combined with mining and oil are also important activities in the Territory. High rainfall and rapidly-flowing streams afford the basis for a number of hydro-electric schemes which are being developed not only on individual farms but also for the larger towns.

The Administration is endeavouring, through its various district officers, to carry out the United Nations Charter of developing the country for the benefit of the native community. The natives are scattered generally over the whole of the islands in a large number of small tribes or families, many of whom have their own individual language and are not combined in any way into large groups. The tribes are experienced agricultural units, cultivating their own sweet potato, taro, bananas and rice as food products. Protein is notably short in the native diet. Fowls and pigs are kept by families but only in small numbers and the native tribes carry out an extensive burning programme to supply themselves with wild rodents and other game for food purposes. This results largely in destruction of fairly big areas of the natural vegetation of rain forest with the production of extensive areas of grasslands covered with kunai and kangaroo grass (themeda).

The present Government policy is to develop the country through the native tribes by encouraging expansion of native co-operatives for the cultivation of rice, coffee, cacao and coconut. Limited white settlement is being encouraged but only under rather strict supervision, and intending settlers can only acquire land under lease in certain restricted districts and have to show the Administration that they have sufficient finance. The Administration will acquire land for such purposes only with the agreement of the native tribes.

The older agricultural areas are growing largely copra, located principally on the northern coastal fringes of New Guinea and New Britain and along the flat eastern edge of New Ireland. Present prices for copra are reasonably satisfactory, but the health of some of the plantations is not of the best. Improvement of fertility of these areas is following on the introduction of legumes into the kunai ground cover under the coconut palms and the introduction of grazing cattle onto the area. This, however, is in its very early stages at the present time. Extensive replanting of coconut plantations is under way and native villages are being encouraged to undertake also the growing of coconuts. Rubber plantations are located principally on the southern coastal regions of New Guinea but there does not appear to be any serious attempt to further expand this industry, owing to difficulties of disease and shortage of native labour. Native villages are also being encouraged to grow upland rice, principally to supply native food stuffs, but the Administration is also investigating large-scale growing of rice on the extensive lowlands bordering on the Markham and Ramu rivers in northern New Guinea. A very active programme is at present under way in encouraging both cocoa and coffee—cocoa in the lowland tropical regions and coffee in the highlands. These two crops are highly profitable at the present time, particularly in the case of the former which gives a gross return of something of the order of £150 per acre. An extensive experimental programme is being carried out at the Departmental Experimental Stations on a wide variety of problems associated with the growing of these crops, covering breeding, fertilizer and cultivation practices.

On the animal production side, little is being done at the present time. Romney Marsh sheep were introduced to the highlands by Sir Edward Hallstrom some few years ago but they have not been a success, owing largely to fertility problems under the high temperature conditions and the very great prevalence of parasites despite treatment by anthelmintics. Conditions appear much more suited to cattle but this industry is in a very low state at the present time due chiefly to the fact that stock numbers were reduced almost to extinction during the war period. The Department is introducing nucleus studs imported from the mainland with the idea of building up numbers from locally bred stock since transport charges on imported cattle are very high. Generally speaking, British breeds do not appear to be particularly well suited to the area but it may well be that hybrids with Asiatic-type cattle may be more satisfactory. Some herds of Zebu hybrids grown by local settlers are showing promise.

One of the greatest handicaps at the moment is satisfactory pastures for stock grazing. Native pastures are largely kunai of very low nutritive value and although some endeavours

have been made to introduce legumes such as centrosema, pueria, desmodium and mimosa, these are only in their very early stages and intensive work is needed in the endeavour to find a satisfactory legume for the Territory.

The Administration is centred in Port Moresby with a number of Departments on somewhat similar bases to those in the Australian States. The Department of Agriculture is subdivided into Divisions of Plant Industry, Animal Industry, Fisheries and Agricultural Extension. The Division of Plant Industry has quite an extensive programme of research and experimental work largely concerned with the main crops of cocoa, coffee, coconuts, rubber and rice, with a number of field Experiment Stations. Other sections include soil survey, plant introduction, plant pathology and entomology. Agricultural Extension officers are located at centres throughout the Territory and work closely in conjunction with native and European agriculturalists. They also have Administration Stations located in the different districts. Animal Industry is staffed chiefly by veterinarians and is therefore considerably stronger on the disease control side than on animal husbandry activities. Pasture production is controlled by this Division.

"Eradication of Insect Pests"

Presidential Address delivered by Mr. P. N. Forte, Senior Entomologist, Western Australian Department of Agriculture

"Can insects be eradicated?" This question was answered with a confident yes by Mr. P. N. Forte in his recent Presidential Address. To the economic entomologist eradication has always meant the destruction of all members of a species of insect in any particular area. However there always has been a school of thought which maintained this was impossible, although in recent years there has been a change in the whole attitude to insect pest eradication.

Modern research methods, and newer, lasting insecticides such as dieldrin, have provided the tools for possible eradication, the success of which depends upon:—

(1) Devising an effective method of control.
(2) Implementation of a plan by legislation.
(3) Co-operation of all states affected.
(4) Full co-operation of the public.

Many successful eradication campaigns have been carried out in various parts of the world. The Mediterranean fruit fly was eliminated from parts of 20 counties in Florida at a cost of $7,000,000, and citrus white scale, Colorado beetle, and white garden snail have been eradicated from specified areas.

The malaria carrying mosquito (*Anopheles gambiae*) which caused 20,000 deaths in Brazil in 1938 and 130,000 deaths in Egypt in 1943 has been eradicated from these areas. In Western Australia, 16 separate outbreaks of codling moth have been eradicated, and this has been of enormous benefit to the State.

In Australia one of the most serious of insect pests is the Argentine Ant. This ant was first reported in Melbourne in 1939 and later Albany and Perth in 1941. Finally the ant was located in Sydney in 1951, but the area infected there is still relatively small. The insect is a lover of moisture and would be able to infest all the towns in Australia, all the river and swamp regions as well as irrigated areas. Thousands of square miles could become infested, and thus it is important to eradicate this insect from the 55½ square miles or so which it now occupies. There are no natural enemies and control is thus solely restricted to chemical methods by the use of insecticides.

Initially DDT was the most suitable material used but this was replaced by chlordane which proved more effective. Experiments have shown that newer insecticides such as aldrin and dieldrin were superior to chlordane and that the residual effect was greater. In Western Australia an intensive campaign was initiated in 1954 by the State Government and the Department of Agriculture was co-opted to implement the campaign. By May 1955, 7,200 acres had been treated and re-infestation has been negligible due no doubt to the persistency of dieldrin. It will cost the people of W.A. £500,000 to eradicate the Argentine Ant, but will save millions in future years, not only in this State, but in the other states of Australia.

"Bloat Research in New Zealand"

Dr. J. Melville, Director Waite Institute, addressing Plant Industry Research Officers, C.S.I.R.O., Canberra.

Dr. Melville stressed the importance of looking at the soil-plant-animal complex as an entity and the danger of looking solely at any one aspect of the complex.

As an example of the study of the plant-animal complex he quoted the work of Dr. Johns on the Aetiology of bloat. Metabolic disorders of stock are becoming increasingly important in the New Zealand pastoral industry—particularly bloat, hypocalcaemia and hypomagnesaemia. Of these, bloat takes a devastatingly high annual toll.

Grasslands division of D.S.I.R. were in an extremely fortunate position for studying the aetiology of bloat in that the pastures for a radius of 10 miles around Palmerston North were particularly notorious for bloat prevalence.

Johns took two pairs of identical twins and one dry cow which were known to be particularly bloat susceptible and were fed, in stalls, measured quantities of Red Clover. He was able to produce bloat experimentally and measure its severity. He found two major groups of factors in the aetiology of bloat—a plant factor usually associated with legumes and animal factors.

Relief was always obtained by drenching with anti-foaming agents—and they were a suitable preventative, thus ensuring a therapeutic measure. The eructation mechanism was not inhibited during the onset of bloat. There was no relationship between the rate of intake and bloat produced.

It appeared that there were at least three possible foam-producing systems in clover bloat:

1. Saliva.
2. Saponins.
3. Proteins and their breakdown products.

Research was being continued into these mechanisms.

Work at Palmerston North was also being done on rumen physiology in relation to the pasture. Permanently fistulated sheep were being used and the volatile fatty acid and ammonia production was being measured in relation to the proximate analysis of pasture fed.

Dr. Melville pointed out that the rumen was the common meeting ground of the plant and animal workers, and only by an integration of this work could an understanding of the pasture complex be obtained.

"The 1955 S.A. Locust Outbreak"

D. C. Swan, Waite Institute and J. D. McAuliffe, Department of Agriculture, South Australia.

Mr. Swan said that major outbreaks have occurred in South Australia in 1890, 1934, 1947, 1950 and 1955. It appeared that plagues were likely to occur much more frequently than had been previously thought.

He considered the term "locust" better than "grasshopper." *Chortoicetes terminefera* covered most of Australia and has been found on the tip of Tasmania. A separate race appeared to exist in W.A.

The insects migrate from the pastoral areas to the agricultural areas in the autumn and lay their eggs. These hatch out in the spring when environmental conditions are suitable. With increasing observations being made the picture of the course of migration is now becoming clear.

Mr. McAuliffe dealt with the subject of the field activities in the control programme. The big problem in some areas was the lack of equipment, but the introduction of army jeeps with Sayers exhaust sprayers once accepted by the landholders overcame this difficulty. Small equipment from hand knapsack sprayers, boom sprays, Sayers exhaust sprayers, air blast and sand blast equipment to aeroplanes, all proved useful under particular circumstances. After hoppers took to the wing the aerial campaign got under way; the discovery that the use of water as a carrier for insecticide was as effective as diesoline, simplified matters.

The hoppers were spotted in the evenings and sprayed before they moved off in the morning. On one occasion a good kill was obtained while hoppers were on the wing, but all equipment must be quite close to make this possible, as 3 tankfuls were necessary to kill the swarm.

The experience gained in the campaign will mean that much more effort will be expended before the hoppers fly, and this, together with ground spraying at night time will largely eliminate the need for aerial spraying.

Mr. McAuliffe said Gammexane, Aldrin, Dieldrin and Toxaphene were all used effectively. Dieldrin was the major insecticide used as it was cheaper and readily available. However, it is not as quick as Gammexane, and took up to 48 hours to kill during cool weather. Insecticide was provided by the Government and handled through local district councils.

INSTITUTE AFFAIRS (STOP PRESS)

Mr. A. J. Anderson.

This photograph of Mr. A. J. Anderson has just come to hand.

Mr. Anderson was recently awarded the Australian Medal of Agricultural Science. This Award is described on page 160.

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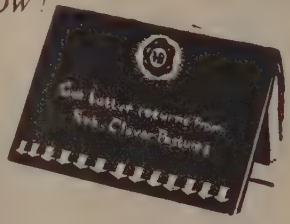

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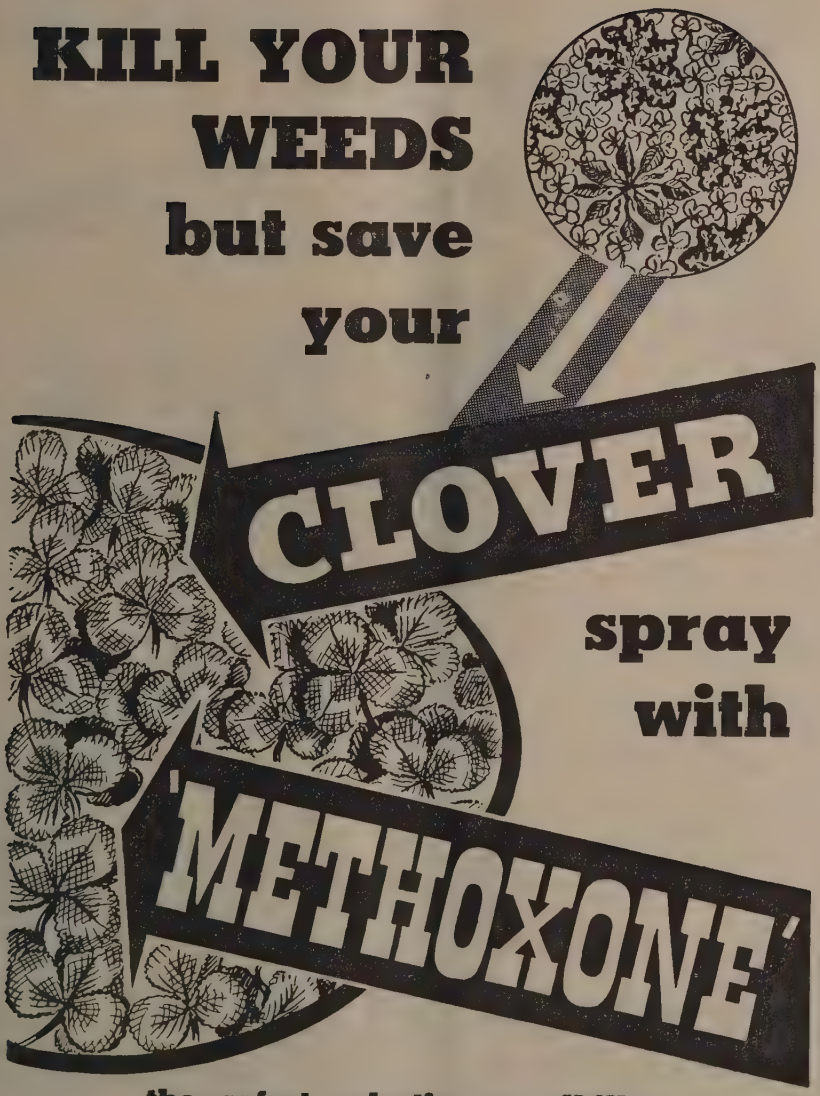

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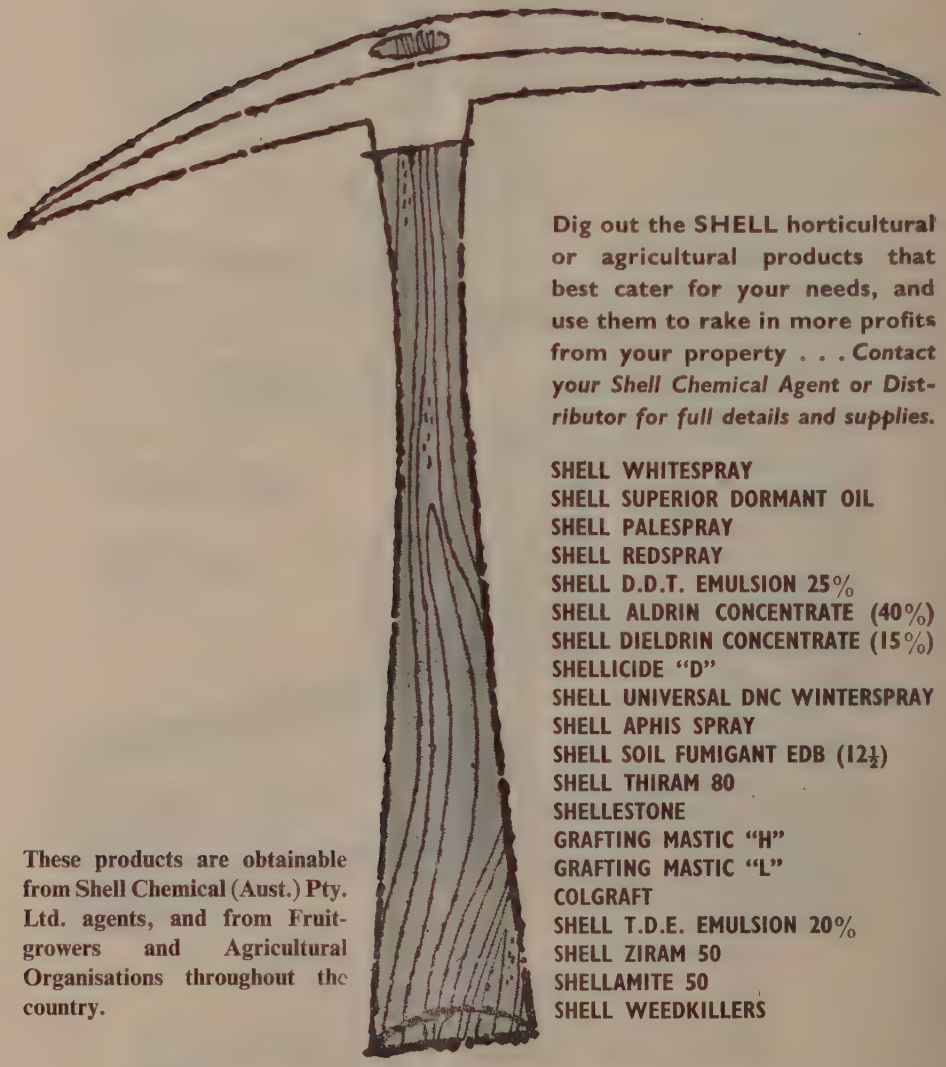

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FEDERAL PRESIDENT FOR 1956

DR. E. T. EDWARDS

Dr. E. T. Edwards, Director of Public Relations and Publicity at the University of New England, Armidale, N.S.W. has been elected President of the Australian Institute of Agricultural Science for 1956.

Dr. Edwards has been closely associated with the Institute of Agricultural Science ever since its inception in 1935, and as the Honorary Secretary of the Sydney University Agricultural Graduates' Association for several years prior to this date, he was largely responsible for the organisational work which culminated in the foundation of the Institute on an Australia-wide basis.

Dr. E. T. Edwards

At the Inaugural Meeting of the Institute in Melbourne in 1935, Dr. Edwards was appointed the first Business Manager of its Journal. He was also the first Secretary of the N.S.W. Branch, and served for many years on the Institute's Federal Council, its Journal Editorial Committee, and also as Chairman of the Membership Qualifications Committee. Dr. Edwards was President of the N.S.W. Branch in 1943.

Dr. Edwards has had wide experience in agricultural research, extension work and business administration. He graduated B.Sc.Agr. from Sydney University in 1928 and was awarded his M.Sc.Agr. degree in 1935 for research work on a new seedling blight disease of maize. He was awarded a Service Fellowship by the Commonwealth Fund of New York in 1937 and spent the following two years doing plant pathological research at the University of Wisconsin, U.S.A., where he was awarded his Doctor of Philosophy degree in 1939.

Dr. Edwards worked as a plant pathologist in the Biological Branch of the N.S.W. Department of Agriculture from 1928 to 1945, when he resigned to become the Editor-in-Charge of a monthly agricultural paper being produced by National Press Pty. Ltd., Sydney.

During 1950, he spent nine months doing publicity work for the C.S.I.R.O. sheep and wool research programme, visiting laboratories and field stations in all parts of he Commonwealh.

In 1952, he was appointed Australian Sales and Advertising Manager for a group of associated companies with extensive interests in pest control and the supply of agricultural chemicals throughout the Commonwealth. In 1953, he visited U.S.A., Great Britain, Sweden, Holland and Germany investigating the latest developments in techniques and materials for industrial and agricultural pest control.

He resigned from these companies in July, 1955, to accept his present position of Director of Public Relations and Publicity at the University of New England, Armidale, New South Wales.

THE AUSTRALIAN MEDAL OF AGRICULTURAL SCIENCE

1956 AWARD TO MR. A. J. ANDERSON

A. J. Anderson, B.Sc. (Agr.), Senior Principal Research Officer, C.S.I.R.O., Canberra has been awarded the Australian Medal of Agricultural Science for 1956.

The award to Mr. Anderson was made for his outstanding contribution to the knowledge of the basic needs of plants. His work has made possible extensive pasture improvements over millions of acres in southern and eastern Australia, which were formerly regarded as poor and unproductive land.

Mr. Anderson is an acknowledged world authority on the role of the trace element molybdenum in plants. By invitation in 1955, he attended a meeting at the Johns Hopkins University at Baltimore, U.S.A. to deliver an address on this subject. The first demonstrated response of a pasture to molybdenum was announced by Mr. Anderson in the Journal of the Australian Institute of Agricultural Science in 1942, when he described an experiment conducted at Meadows, in South Australia.

Mr. Anderson is noted for his ability to see the practical applications of research on pasture plants. He has led intensive research into sulphur deficiency in pasture, boron deficiency, particularly in lucerne, and the residual effects of heavy dressings of superphosphate which have been so important for the rapid establishment of improved pastures on the Southern Tablelands of New South Wales.

(See photograph of Mr. Anderson on Page 157)

PERSONAL NOTES

Australian Capital Territory.

Dr. M. J. T. Norman has been recently appointed to the Land Research and Regional Survey Section, C.S.I.R.O., as agrostologist at the Katherine Research Station, N.T. He was formerly on the staff of the Grassland Research Institute, Hurley, England.

Mr. R. O. Slatyer, of the Climatology Unit, L.R.R.S. Section, has returned to Canberra after a 12 month visit overseas. During his visit Mr. Slatyer visited organizations concerned with research in agricultural climatology, and carried out research into fundamental aspects of soil-plant-atmosphere-water relationships. Most of his time was spent with Dr. P. J. Kramer of Duke University.

Mr. W. H. Litchfield of the C.S.I.R.O. Division of Soils has been transferred from Brisbane to Canberra where he has been seconded to the Land Research and Regional Survey Section as pedologist to the Mainland Regional Survey unit.

Mr. C. S. Christian, Officer-in-Charge of the Land Research and Regional Survey Section of C.S.I.R.O. paid a brief visit to Syria in April at the request of the UNESCO Arid Zone Advisory Committee. The purpose of the visit was to advise UNESCO and the Syrian authorities about the methods and organization for a comprehensive integrated resources survey of an arid zone area at present utilized by nomadic tribes for seasonal grazing by sheep, goats and camels.

Plant Industry Division, C.S.I.R.O.

Drs. N. K. Boardman, J. N. Phillips and *P. A. Trudinger* are recent appointees to the Biochemistry Section at Canberra.

Mr. I. A. M. Cruikshank of Plant Diseases Division, D.S.I.R., New Zealand, has arrived to take up a position with the Microbiology Section.

Mr. A. H. Gibson has taken up an appointment in the Microbiology Section. He will be going overseas very shortly on a C.S.I.R.O. scholarship to carry out research on rhizobium under Dr. P. S. Nutman at Rothamstead.

Dr. P. S. Nutman will be returning to Rothamstead from Canberra in May.

Staff Overseas.

Mr. Keith Spencer is making headway with his studies at the Mississippi State College.

Dr. R. D. Brock is in the U.S.A. working on radiation genetics.

Mr. W. Hartley and family have sailed for Europe.

Miss N. Burbidge is on a collecting trip in Northern Australia with particular emphasis on Nicotiana and Graminae.

Visitors to the Division.

Dr. J. Melville, Director of the Waite Agricultural Institute visited the Division in April, and had discussions with all the groups. He also gave the research staff a talk on some of the work that was in progress at Grasslands Division D.S.I.R., Palmerston North, New Zealand.

New South Wales

At Graduation day at the University of Sydney on 30th April last *Associate Professor J. M. Vincent* received the degree of D.Sc.Agr.

Four earlier graduates received the degree of M.Sc.Agr. They were *Mr. C. I. Davern*, now on

the staff of the Division of Plant Industry of the C.S.I.R.O. at Canberra; *Mr. K. J. Hutchinson* who is on the staff of Roseworthy Agricultural College; *Mr. E. J. Martin*, an officer of the Tasmanian Department of Agriculture and *Mr. N. S. Snow* who is a teaching fellow in the School of Agriculture at Sydney University.

Twenty-two 1956 graduates received the degree of B.Sc.Agr., six with Honours and the University Medal at graduation was also awarded to *Mr. A. H. Gibson.*

The following graduates have recently joined the staff of the N.S.W. Department of Agriculture:

Mr. P. Broué as agrostologist at Berri.

Mr. R. D. Wholley as agrostologist at Trangie.

Mr. G. Swain as agrostologist at Wollongbar.

Miss K. Payne as vegetable breeder at Hawkesbury Agricultural College.

Mr. K. Scott has resigned from the Education Department in N.S.W. and joined the Department of Agriculture of N.S.W. as horticultural research officer on fruit storage and transport problems.

Mr. D. E. Finlay, formerly plant breeder in the N.S.W. Department of Agriculture, is now on the staff of the School of Agriculture, University of Sydney as teaching fellow in genetics and plant pathology.

Mr. D. G. Carter, at present with the University of Sydney field unit studying pasture problems at Lismore has been awarded a Rotary International Scholarship for post-graduate study overseas and will shortly leave for the U.S.A. where he will work on plant nutrition problems at Cornell University.

Obituary—Lyle W. Lockart

Lyle Lockart graduated B.Sc.Agr. from the University of Sydney in 1950. After graduation he was appointed as Wool Metrologist to the Wool Research Laboratory at Trangie, N.S.W. Here he was responsible for development of facilities for fleece measurement. His keen mind and true scientific curiosity led him to investigate various problems of fleece sampling and the development of fleece attributes. To further these studies he was seconded to the N.S.W. University of Technology where he was proceeding to a Ph.D. degree. His degree work, already at an advanced stage, was terminated by his tragic death in an aircraft accident at Narromine on April 14th, 1955.

Although only 26 years old at the time of his death, Lyle had made and was making substantial contributions to his chosen field. His ability, enthusiasm and critical mind will be keenly missed by his friends and colleagues, who extend their sincere sympathy to his parents and relatives.

Queensland

The Chairman of the Farrer Memorial Trust (Dr. R. J. Noble) has announced the award of the Farrer Memorial Medal to *Mr. A. F. Bell*, Under Secretary of the Department of Agriculture and Stock, Brisbane. This award is made annually to commemorate the work of Australian pioneer wheat-breeder, William Farrer, and to recognize distinguished service to agriculture. The medal will be presented at the Annual Congress of the N.S.W. Agricultural Bureau in July, at which Mr. Bell will deliver the Farrer Oration.

The Senior Lecturer in Plant Industry, Q.A.H.S. and College, *Mr. E. C. Tommerup*, has retired due to ill-health.

Mr. L. R. Humphreys, Senior Agrostologist, Department of Agriculture and Stock, has been transferred to "Brian Pastures" pasture research station, Gayndah.

Mr. R. J. Talbot has been appointed to the position of Lecturer in Agronomy, Q.A.H.S. and College.

Following his resignation as Plant Pathologist with the Bureau of Sugar Experiment Stations, *Mr. J. A. Pollock* has commenced duties with the Australian Paper Mills, Petrie, as an Agronomist.

Graduates for 1956 in Agricultural Science were *Messrs. A. F. Cowan, K. S. Chang, R. W. Downes, C. Flynn, F. R. From, R. E. Harrison, D. R. Tait, J. K. Thapa, N. H. Thomson.*

Messrs. Chang, Downes and Thapa are with the Department of Agriculture and Stock, the latter has taken a temporary position only as he will be returning to India towards the end of the year. Mr. Flynn is employed by the Shell Company, Brisbane, and Mr. Thomson has joined the staff at the Q.A.H.S. and College. Mr. Harrison is farming at Beaudesert whilst Messrs. From and Tait are completing Honours courses at the University in Agronomy and Plant Pathology respectively.

South Australia

Mr. N. S. Tiver has been appointed senior agronomist of the Department of Agriculture. *Mr. A. J. K. Walker*, now chief agricultural adviser, was formerly senior agronomist.

Mr. J. K. Powrie, formerly with the Department of Agriculture, has accepted a position at Wagga, N.S.W.

Mr. G. Blackburn, of C.S.I.R.O., Division of Soils and *Mr. R. M. Baker*, of the Department of Agriculture left this month (June) for soil survey work in Brunei, North Borneo.

Mr. L. C. Smith has resigned from the Horticultural branch of the Department of Agriculture to join a commercial firm in Sydney.

Mr. W. G. Allden has resigned from Kybybolite Research centre to take up an appointment as agronomist at the Waite Institute.

Mr. P. E. Geytenbeek has been appointed officer-in-charge of Kybybolite Research Centre. Formerly he worked on soil conservation projects in the Mid and Lower North, the Mallee and Yorke Peninsula.

Mr. A. F. Tideman has left the Department of Agriculture's soil conservation branch to join a commercial firm in S.A.

Victoria.

Mr. W. B. Miller has been appointed Agricultural Superintendent in the Victorian Department of Agriculture, in succession to Mr. J. Brake.

Mr. L. R. Hoult has been appointed Associate Director and General Manager of Brockhoffs Biscuits Pty. Ltd.

Dr. I. D. Marshall was recently awarded his degree of Doctor of Philosophy for work carried out at the John Curtin School of Medical Research, Australian National University, Canberra.

Western Australia

Mr. F. L. Shier, Superintendent of Wheat Farming, who has been engaged on F.A.O. duties in Syria is expected to be returning to Western Australia in June. Mr. Shier has been engaged on the technical problems of sheep management and production in Syria.

Mr. G. H. Burvill has recently been appointed to the position of Chief Plant Research Officer in the Western Australian Department of Agriculture. Mr. Burvill gained his B.Sc.Agric. (Hons.) degree at the University of W.A. in 1930 and the M.Ag. Sc. degree at Adelaide University in 1939. From 1929 to 1947 he was an officer and later head of the Plant Nutrition and Research Branch. Since 1947 he has been Commissioner of Soil Conservation. He has an extensive knowledge of the state and its agricultural industries and problems. In 1954 he visited Africa, where he was an Australian representative on the 5th International Congress of Soil Science, held in the Belgian Cono.

Mr. J. Lawson has rejoined the North West Branch, after a short period with the Rural Broadcasts Division of the A.B.C. He has been posted to the position of Senior Adviser at Carnarvon.

BRANCH NOTES

Australian Capital Territory.

The Annual Dinner was held at University House on Thursday, 22nd March. This was followed by the Annual General Meeting. The following committee was elected:

President	Dr. D. B. Williams
Vice-President	Dr. R. D. Brock
Hon. Secretary	Miss M. Mills
Hon. Treasurer	Mr. J. Lipsett
Hon. Sub. Editor	Mr. H. Lloyd Davies
Committee Members .	Messrs T. T. Colquhoun and Mr. F. Grogan.

The Immediate Past President, Mr. R. M. Moore, automatically becomes a member of the committee.

At the meeting it was agreed that the branch should review the Institute's future to determine what part, if any, the Institute can play in view of the formation of a number of associated bodies.

On Thursday, 10th May, a talk was given by Mr. T. C. Creyke (Agricultural adviser to the High Commissioner for the United Kingdom) on comparisons between U.K. and Australian agriculture. About 40 members and guests were present.

New South Wales

At the Annual meeting in February the following office-bearers were elected for the current year:—

President—Dr. M. C. Franklin.
Vice-President—Mr. A. N. Johnston.
Hon. Secretary—Mr. J. D. McFarlane.
Hon. Treasurer—Mr. C. L. Goldstone.
Committee Members—Assoc. Prof. J. M. Vincent, Miss Barbara J. Carne, Miss Vinleigh Johnson, Mr. M. V. O'Reilly, Mr. P. K. Briggs, Mr. W. J. Greenhalgh.
Hon. Sub Editor—Mr. E. G. Hall.

The retiring President, Mr. A. N. Johnston gave an address "On the relation of the chemical industry to agriculture." He pointed out their growing interdependence, discussed opportunities for agricultural graduates in industry and considered that both industry and the Institute have a joint responsibility in the proper training of agricultural specialists for service in industry, their fields of activity and their conditions of employment.

On 13th April the Branch was entertained by Dr. B. Breyer, of the School of Agriculture, University of Sydney with an illustrated talk on his recent tour of Indonesia, Malaya, Hongkong, Japan and the Philippines. Dr. Breyer was invited to Japan by the Japanese Chemical Society to lecture on his work in the field of polarography in which he is a leading authority. His trip was financed by grants from U.N.E.S.C.O. and the Walter and Eliza Hall Trust. Because of his very good photography, careful observation and keen interest in human affairs he was able to present a very interesting commentary on academic institutions and general conditions in the several countries visited.

Following graduation on 30th April new members of the profession of agriculture were welcomed at a cocktail party on 1st May by the Branch and the Sydney University Agricultural Graduates' Association in the University Union. As previously the function was a great social success. Distinguished visitors were Dr. and Mrs. J. G. Horsfall who were visiting Australia. Dr. Horsfall is Director of the Connecticut State Agricultural Experiment Station and well known for his work on the mode of action of fungicides.

Queensland

The Annual General Meeting of the Queensland Branch was held on 28th March, 1956. The branch office bearers for 1956 are as follows:

President—Professor L. J. H. Teakle.
Vice-Presidents—Mr. N. H. Shaw and Dr. L. G. Miles.
Hon. Secretary-Treasurer—Mr. S. A. Waring.
Assistant Hon. Secretary-Treasurer—Mr. L. A. Edye.
Hon. Branch Editor—Mr. O. W. Sturgess.
Committee Members—Drs. R. N. F. Langdon, D. O. Norris and Mr. G. D. Hubble.

The retiring President, *Dr. L. G. Miles*, delivered his presidential address on "Dry Farming Patterns in Queensland."

Owing to the occurrence of the Anzac Day holiday and the University of Queensland graduation celebrations during the last week in April, the monthly meeting for April was carried over to the 2nd May. The main business for the evening was three short addresses summarising the major points discussed at the Plant Nutrition Conference, Melbourne, February-March, 1956. The three speakers were *Messrs. C. S. Andrews, I. F. Fergus,* and *Dr. D. O. Norris.*

South Australia

On 10th February, Mr. B. G. Coombe, of the Department of Agriculture spoke on "Viticultural Research, and in particular the setting of currants with growth substances."

The annual general meeting was held at the Waite Institute on 9th March and officers for 1956/57 were elected. These were: President, Mr. A. J. K. Walker; Secretary, Mr. M. V. Burton; Treasurer, Mr. N. Crowley; Sub-editor, Mr. C. T. De B. Griffith; Committee, Dr. Quirk, Prof. Donald, Mr. I. Fornachon, Mr. Spurling; Auditors, Mr. J. Harris, Mr. Blackburn.

On 13th April, Mr. D. C. Swan and Mr. J. D. McAuliffe summed up the 1956 locust outbreak, giving biological background and details on control activities.

Tasmania

On 26th April, Prof. H. K. Pratt, a visiting Fulbright Scholar from the University of California, Davis, spoke to a general meeting on "Investigations of Post-Harvest Physiology of Horticultural Crops in California." Prof. Pratt described some of the problems associated with shipping California's produce to the markets of New York and Chicago, with particular reference to tomatoes, lettuce and melons.

Victoria

The Annual General Meeting of the Victorian Branch was held in the School of Agriculture, University of Melbourne on Friday, May 25 and the Committee for 1956 is as follows:—

President	Mr. C. E. Cole
Vice-President	Mr. T. S. Bellair
Hon. Secretary	Mr. J. P. Brien
Hon. Asst. Secretary	Mr. W. T. Parsons
Hon. Treasurer	Mr. J. V. Mullaly
Committee Members	Dr. C. R. Millikan
	Mr. W. B. Mackie
	Mr. R. E. Loder
	Mr. B. F. McKeon
Immediate Past President	Mr. A. L. Tisdall
Hon. Recorder	Mr. J. J. Lenaghan
State Sub. Editor	Mr. J. J. Walker
Professor of Agriculture	Sir Samuel Wadham

Keen interest was shown in Mr. Tisdall's address entitled "Water in the Third Dimension."

Symposium Papers.

The discussions at the Symposium on the Training and Recruitment of Agricultural Scientists held on March 23 were recorded and a statement of the meeting's recommendations is at present being drawn up.

In the meantime, the papers presented, which were made up into a 44 page book and sent to Victorian Branch members one week before the Symposium, have now been despatched to Committee members in each of the state branches and to Council members of the New Zealand Institute of Agricultural Science.

Western Australia

The annual General Meeting was held on 13th April 1956. The following office-bearers were elected:—

President—Dr. R. C. Rossiter.
Vice-President—Mr. S. T. Smith.
Secretary—Mr. B. J. Quinlivan..
Assistant Secretary—Mr. J. Mulcahy.
Treasurer—Mr. J. Parish.
Sub Editor—Mr. D. A. Johnston.
Committee—Messrs. F. Ryan, T. Stoneman, N. Halse, J. Gladstones.

The meeting was followed by the Annual Dinner, after which the Presidential Address by Mr. P. Forte was given on the "Eradication of Insect Pests."

At the Annual General Meeting, Mr. J. Roberts, the Executive Officer of the A.I.A.S., acquainted members with the position as regards Central Office Accommodation and the methods suggested for raising the £10,000 required for the purchase of the proposed building. Mr. Roberts also outlined steps taken to interest private enterprise in the activities and functions of the Institute. This has already been successful in so far that Cuming Smith & Mount Lyell Farmers Fertilizers Ltd. have donated £100 per annum for 5 years to aid the Institute in its work.

BOOK LIST

Notice has been received that the following books on agricultural topics have been published recently.

AZZI, Girolama. Agricultural ecology. *London, Constable & Co.*, 1956, 45/- stg.

BROWN, Dorothy. Methods of surveying and measuring vegetation. (Commonwealth Bureau of Pastures and Field Crops, B. 42), 1954, 35/- stg.

GARRETT, S. D. Biology of root-infesting fungi. *Cambridge, University Press*, 1956, 30/- stg.

JACKS, G. V., BRIND, W. D. and SMITH Robert. Mulching. (Commonwealth Bureau of Soil Science Tech. Communication 49) 1955. 18/9.

KENDALL, Maurice G. Rank correlation methods, 2nd ed. *London, Charles Griffin Ltd.*, 1955, 57/9.

NEW ZEALAND, Dept. of Scientific and Industrial Research, Bulletin 114, Diseases and pests of peas and beans in N.Z. and their control.

NICHOLSON, D. F. Australia's trade relations: an outline history of Australia's overseas trading arrangements. *Melbourne, F. W. Cheshire*, 1955, 42/-.

SCHLIPPE, Pierra de. Shifting cultivation in Africa: the Zande system of Agriculture, London, Routledge & Kegan Paul, 1956, 42/- stg.

SEARLE, Sidney A. *ed.* Plant climate and irrigation. Chichester, Chichester Press Ltd., 1954, 39/9.

SWAINE, D. J. The trace element content of soils. (Commonwealth Bureau of Soil Science Technical Communication No. 48), 1955, 31/3.

WISHART, John and SANDERS, H. C. Principles and practice of field experimentation, 2nd ed. (Commonwealth Bureau of Plant Breeding and Genetics Technical Communication 18), 1955. 26/3.

WYLLIE, James. Farming records and accounts. *London. Butterworth's Scientific Publications*, 1953, (Wye College Series No. 1). 30/- stg.

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Before being required to assume the full responsibilities of the position, the appointee will work for some time in the Organisation's Head Office in Melbourne, and with senior administrative officers of the Division in Melbourne, or Sydney in order that he may become conversant with administrative practices within the Division and the Organsation as a whole.

Commencing salary will be determined within the range of Senior Technical Officer (£1,353-£1,623 p.a.) or Technical Officer (£903-£1,353 p.a.).

The appointment will be conditional on a satisfactory medical examination and the successful applicant will be asked to serve for an initial probationary period of up to twelve months before being confirmed in his appointment as an officer of the Organisation. If so confirmed he will be required to contribute to, and eligible to receive benefits from either the Commonwealth Superannuation Fund or the Commonwealth Provident Account.

Applications referring to appointment No. 200/34 and stating full name, place, date, and year of birth, marital status, present employment, particulars of qualifications and of war service, if any, accompanied by copies of not more than four testimonials should reach the Chief, Division of Animal Health and Production, cnr. Flemington Road and Park Street, Parkville, N.2, Victoria, by 13th July, 1956.

Further information may be obtained by personal enquiry, by telephone, or letter to—

Mr. J. H. Elliott,
Sheep Biology Laboratory,
P.O. Box 144,
Parramatta, N.S.W. Telephone YA 3721.

or in Melbourne to—

Mr. A. J. Vasey,
C.S.I.R.O., Divisional Office,
Cnr. Flemington Road and Park Street,
Parkville, N.2, Victoria. Telephone FJ 4659.

PUBLIC SERVICE OF SOUTH AUSTRALIA

Applications for the position set out hereunder will be received by the Public Service Commissioner, 31 Flinders Street, Adelaide, until and including Monday, 16th July, 1956.

Applicants should state full names, address, date of birth, marital status, academic qualifications, practical experience, and give particulars of war service (if any). Copies only of testimonials should be submitted with the application.

The appointee may be required to contribute to the Government Superannuation Fund.

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Department of Agriculture.

ADVISER IN ANIMAL PRODUCTION (PIG HUSBANDRY).

Salary range: £1,400/£1,550 or £1,200/£1,450 per annum, according to qualifications and experience of person selected.

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The appointee will be required to conduct investigations into the problems of pig husbandry and production.

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Preference will be given to applicants with a degree in Agricultural or Veterinary Science.

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C.M.U. WEED KILLER. This material is based on 3-(p-chlorophenyl)-1, 1-dimethylurea. It is a non-poisonous total weed killer, which is effective for long periods. At very low dilution it is ideal for pre-emergence control of weeds in crops as divergent as sugar cane and asparagus.

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